



A PROGRAM SPONSORED BY THE PORTUGUESE SCIENCE AND TECHNOLOGY FOUNDATION

MIT PORTUGAL 2006-2011

A network of advanced studies involving Portuguese Universities and the Massachusetts Institute of Technology

Advanced training Programs:

- Bioengineering Systems
- Sustainable Energy Systems
- Transportation Systems
- Engineering Design and Advanced Manufacturing

Degree awarding institutions:

- New University of Lisbon (Faculty of Sciences and Technology)
- Technical University of Lisbon (IST and ISEG)
- University of Coimbra (Faculty of Sciences and Technology and Faculty of Economy)
- University of Lisbon (FCUL)
- University of Minho (School of Engineering)
- University of Porto (FEUP)

**Submitted to the analysis of the External Review Committee
and the Portuguese Science and Technology Foundation**

DRAFT

March 2011

Executive summary

A unique post-graduate education network of intense and wide ranging collaboration between Portuguese Universities, research institutions, companies, and the Massachusetts Institute of Technology (MIT), has been funded by the Portuguese Science Foundation (FCT) for the period 2006-2011. The network offers Portugal's a truly international education program serving as a model for the intersection of engineering education, research, innovation and entrepreneurship.

A total of 6 Portuguese universities, 20 Portuguese research centers and national laboratories, together with 25 MIT departments, and all 5 Schools within MIT are involved in this ongoing partnership. Seven Doctoral, Master's of Business Engineering and Master's of Science programs have been created in the areas of Bioengineering, Sustainable Energy and Transportation Systems and Engineering Design and Advanced Manufacturing. These programs host currently 276 PhD and 60 Master's students, from over 44 countries. And there are already 89 Master's graduates. Program applicants include graduates from some of the leading schools in Europe, Asia and the Americas. Both the number and quality of the applicants has increased each year.

This advanced studies network is dedicated to achieving a major goal: to create a new generation of leaders with unique knowledge and a global perspective, who can assume key positions in industry and research in order to make a critical contribution to Portugal's future economic growth and reach into international markets. This approach was developed by bringing together a dynamic consortium of universities across Portugal (Fig. 1), with the best of MIT educational and research expertise, creating high quality teaching and research.

The program has developed national degrees where leading engineering schools working with schools of economics offer shared globally competitive world class academic programs. Students frequently rotate between Portuguese universities for different parts of their curriculum and receive joint degrees awarded in association with all the participating universities.

The Bioengineering Systems (BIO) PhD program provides teaching and training at the intersection between engineering, life sciences, and innovation, and aims at educating a new generation of leaders in bio-engineering, with a strong emphasis in technical innovation, leadership and systems thinking.

Twenty two students of the first two classes of the program (started in 2007 and 2008) have already spent, or are currently spending, extended time at MIT conducting a very important part of their research work plan jointly with Portuguese and MIT faculty supervision. The main PhD research areas are: a) Stem Cell Bio-Engineering and Regenerative Medicine; b) Bioprocess and Biomolecular Engineering; c) Biosystems Innovation, Management and Policy; d) Computational Bioengineering, Genomics, Systems and Synthetic Biology; e) Biomedical Devices and Technologies: Hybrid Human - Machine Systems; f) Neurosciences (Molecular to Systems Neurobiology and Brain Diseases).

During their first year students are involved in extended innovation and entrepreneurship activities (Bio-Teams course), where they work in teams on building go-to-market strategies for selected emerging

breakthrough technologies. This innovation hands-on approach course creates an entrepreneurship drive, skills and gusto in the students who have already originated two start-ups 'Cell2B' (3 students) and 'SilicoLife' (2 students). Another student has already an international patent licensed by a Portuguese biotech company.

The Engineering and Design Advanced Manufacturing (EDAM) area offers a PhD program, Leaders for Technical Industries (LTI), and a Master's of Business Engineering, Technology Management Enterprise (TME), which focus on product and process innovation and complex decision making, taking into account economics, management and social aspects.

The programs are designed to be in close connection with technically advanced industries. All LTI students complete an internship in an industrial environment where they develop business integrated research. TME students are usually professionals from industry and they do their thesis research in a topic related to their professional activity at the company where they work.

The target industrial sectors are the automotive, aerospace and medical devices industries. This selection takes into account the current Portuguese industrial profile, and the industrial sectors in which a higher innovative potential is expected over the coming years. The scope and associated proposals for the PhD program are defined and prepared in collaboration between program's faculty and industry leaders. As a result, all the PhD research themes are industry oriented. PhD student's research can be grouped in three main areas: a) Engineering Design and Innovation, b) Engineering Design Management, c) Manufacturing Technologies and Industrial Management.

A wide range of Portuguese and international engineering and technology industries have received LTI students, including Rolls Royce (UK), General Motors (USA), Continental-Mabor (PT), Volkswagen-AutoEuropa (PT), Hovione (PT), TMG-Automotive (PT), Iber-Oleff (PT), Celoplas (PT). Students are also encouraged to carry out part of their research at MIT.

The Sustainable Energy Systems (SES) area has created integrated educational initiatives for both a PhD and a Master's of Business Engineering in Sustainable Energy Systems. Each program challenges students to apply a systems approach to energy research with the ultimate objective of creating and applying knowledge for the design and implementation of sustainable energy systems. These programs focus in core areas of energy systems within a multidisciplinary engineering systems framework. They include engineering, economics, policy, technology, control and management solutions necessary to design and implement alternative energy strategies, utilizing energy systems analysis and design. Students have the opportunity to learn about the practical application of energy strategies through real-world research case studies conducted in collaboration with industry partners. Two research test beds, which integrate many of the PhD student's research theses, are developed in the context of a) isolated systems: 'Green Islands' and b) urban systems: 'Sustainable Urban Energy Systems'. The Green Islands Project focuses on developing advanced energy systems models to maximize the integration of renewable energies in a sustainable energy future for the Azores archipelago, and the Sustainable Urban Energy Systems topic analyze the many dimensions of efficiently managing the Lisbon and Porto urban systems, from the urban metabolism to sustainable mobility. The ultimate goal of the SES programs is to

train a new generation of professionals to play leadership roles in implementing sustainable energy policies, and in developing new business opportunities in the area of clean energy. These projects involve companies like Electricidade de Portugal (EDP), Electricidade dos Açores (EDA), EFACEC, GALP Energia or Novabase.

The Transportation Systems area offers two degrees: PhD and MSc. The overall aim of these educational programs is the development of a cadre of transportation researchers and professionals who are trained at the system level in the design and management of a technology-intensive, intermodal transportation system.

The doctoral program in Transportation Systems (DPTS) covers all transport systems topics, from transport policy and planning to infrastructure design and maintenance, at various spatial levels (from international to local), and for the various modes (air, rail, road, etc.). Up to now, the main focus areas have been: a) air transport systems; b) high speed rail systems; c) land-use/transport systems; d) innovative urban transport modes/services; e) intelligent transport systems; and f) traveler information systems.

The Master's in Complex Transport Infrastructure Systems (CTIS) builds on three key domains: engineering and project management, financing and contracts, and policy and institutions. This formula grants its graduates an advantageous position when seeking jobs in complex settings. There are 8 major international companies sponsoring scholarships for this program: Alstom, Bento Pedroso / Odebrecht, BRISA, IMTT – Instituto da Mobilidade e Transportes Terrestres, Mota-Engil, RAVE, Refer and Siemens.

Student surveys and faculty interviews indicate that MIT Portugal is successful in attracting an excellent student cohort. MIT Portugal students are reported to show a greater degree of independence on their work, more precise goals, and often a stronger commitment to achieve these goals. They also have a more significant background in industry, and are more prone to work in industry and become entrepreneurs after graduating. Faculty feels that their own teaching style has become significantly more geared towards innovation and management as a result of participating in MIT Portugal. The faculty recruits are benefiting greatly from participating in this network, receiving a noticeable “boost” to their career, increasing their career opportunities, experiencing a rapid expansion of their professional networks, and enjoying important new input into their research work.

Students describe their visit to MIT as extremely positive and highly influential, with strong gains in new methodological approaches or areas of interest, all of which improves their research. Portuguese junior faculty state that visits to MIT are proving highly influential for their teaching practice.

The conclusion from the whole student evaluation exercise (including alumni) is one of high levels of satisfaction with the quality of the network overall with the level of supervision, with the range of skills on offer, and with the general administration and structuring of the research and learning processes.

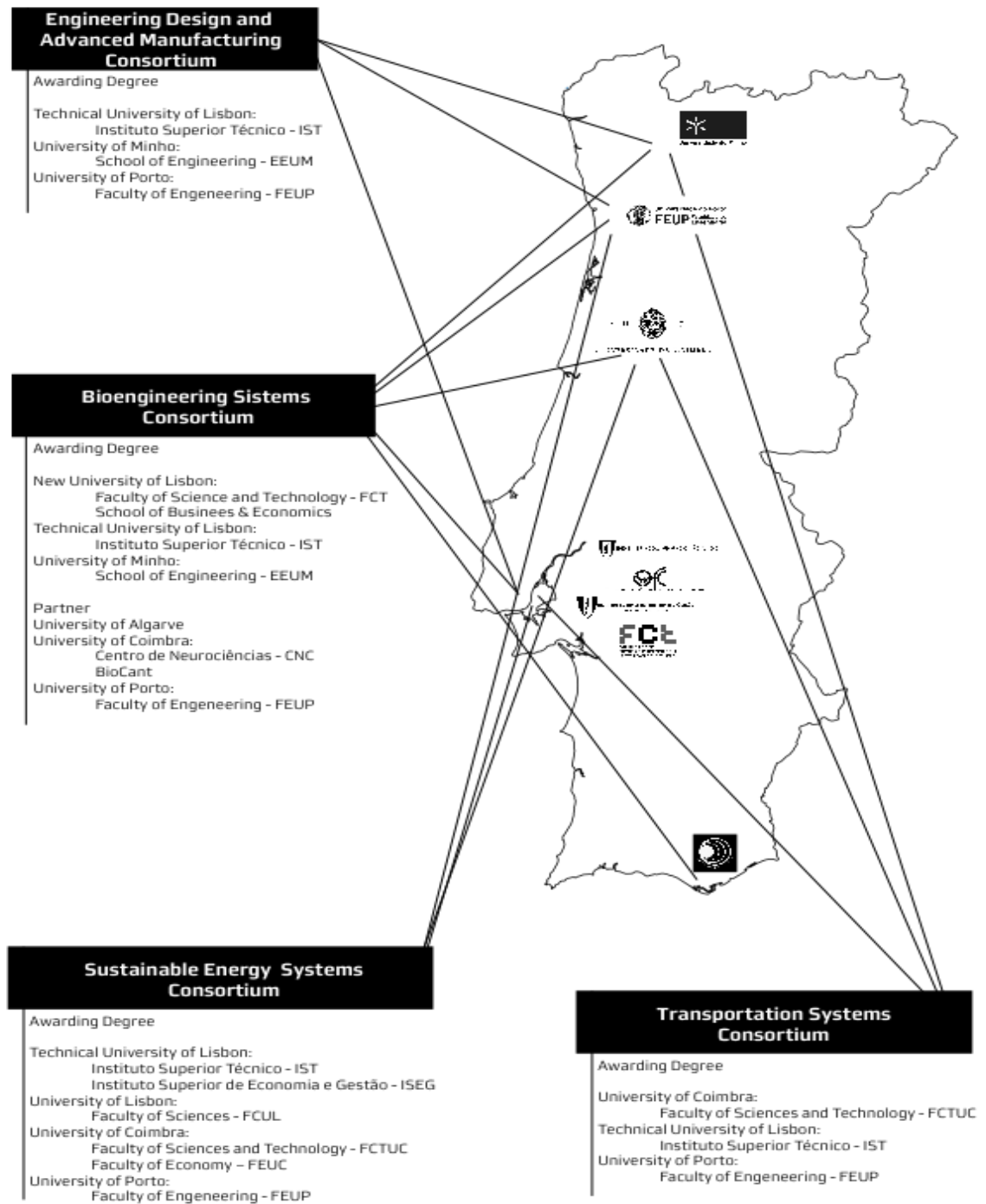


Fig. 1: Consortium of universities (and its respective schools) awarding the degrees offered in the context of the MIT Portugal network.

Table of Contents

Executive summary	1
1. Introduction: A network of advanced studies throughout Portuguese Universities and MIT 8	
2. Doctoral programs.....	10
2.1. Bioengineering Systems.....	10
2.1.1. Overview	10
2.1.2. Structure	13
2.1.3. New courses and faculty involved	14
2.1.4. Use of open-source community-based tools for learning	14
2.1.5. Benchmarking	14
2.1.6. Student highlights	16
2.1.7. Educational initiatives	17
2.1.8. PhD theses.....	18
2.2. Leaders for Technical Industries.....	38
2.2.1. Overview	38
2.2.2. Structure	41
2.2.3. Student highlights	42
2.2.4. New courses and faculty involved	43
2.2.5. Use of open-source community-based tools for learning	43
2.2.6. Benchmarking	43
2.2.7. Educational initiatives	48
2.2.8. PhD theses.....	49
2.3. Sustainable Energy Systems.....	62
2.3.1. Overview	62
2.3.2. Structure	66
2.3.3. Student highlight.....	70
2.3.4. New courses and faculty involved	71
2.3.5. Use of open-source community-based tools for learning	71
2.3.6. Benchmarking	72
2.3.7. Educational initiatives	76
2.3.8. PhD theses.....	79
2.4. Transportation Systems.....	96
2.4.1. Overview	96
2.4.2. Structure	97
2.4.3. New courses and faculty involved	98

2.4.4.	Use of open-source community-based tools for learning	98
2.4.5.	Benchmarking	98
2.4.6.	PhD theses.....	106
3.	Master’s of Business Engineering (MBE) and Master’s of Science Programs (MSc)	114
3.1.	Complex Infrastructure Transportation Systems MSc.	114
3.1.1.	Structure	114
3.1.2.	New courses and faculty involved	114
3.1.3.	Use of open-source community-based tools for learning	115
3.1.4.	Sponsors.....	115
3.1.5.	Benchmarking	115
3.1.6.	Educational initiatives.....	118
3.2.	Sustainable Energy Systems.....	124
3.2.1.	Overview	124
3.2.2.	Structure	125
3.2.3.	Student highlights	127
3.2.4.	Alumni profiles.....	128
3.3.	Technology Management Enterprise.....	134
3.3.1.	Overview	134
3.3.2.	Structure	136
3.3.3.	Student’s highlights.....	137
3.3.4.	Alumni profiles.....	138
4.	Faculty exchange: training the trainers	141
5.	Educational programs in numbers.....	144
5.1.	Doctoral programs	144
5.1.1.	Applications.....	144
5.1.2.	Students	146
5.1.3.	Scholarships	147
5.1.4.	Selectivity	148
5.2.	Master’s programs	149
5.2.1.	Applications.....	149
5.2.2.	Students	150
5.2.3.	Selectivity	152
5.3.	MIT Research assistants (RAs).....	153
6.	Assessment of educational programs.....	154
6.1.	Evaluating achievements	154
6.1.1.	Overview	154
6.1.2.	Re-designing engineering curricula and building human resources in innovation and entrepreneurship	154
6.1.3.	Attracting a strong, international cohort.....	155
6.1.4.	Mobility and networking.....	156

6.1.5.	I-teams	157
6.2.	Student's evaluation of educational programs	160
6.3.	Student's evaluation of the network.....	161
6.3.1.	Overview	161
6.3.2.	Alumni survey	162
6.3.3.	Doctoral student survey.....	162
6.3.4.	Entering student survey	163
6.3.5.	Exiting student survey.....	163
7.	Perspectives for the future	164
7.1.	Lessons learned.....	164
APPENDICES	166

1. Introduction: A network of advanced studies throughout Portuguese Universities and MIT

The MIT Portugal Program promotes a unique post-graduate network of intense and wide ranging collaboration between Portuguese Universities, research institutions, companies, and the Massachusetts Institute of Technology (MIT), funded by the Portuguese Science Foundation (FCT).

The Focus Areas were: Bioengineering Systems; Sustainable Energy; Transportation and Engineering Design for Advanced Manufacturing.

This approach was developed by bringing students from all over the world to study and conduct research in Portuguese universities. This partnership has succeeded in enhancing the international dimension of Portugal's higher education system in these domains. The seven Doctoral and Master's of Business Engineering and Master's of Science programs host currently 276 PhD and 60 master's students, from over 44 countries. And we have already graduated 89 students from the Master's degrees. The efforts to create this educational platform are dedicated to achieving a major goal: to create a new generation of leaders with unique knowledge and a global perspective, who can assume key positions in industry and research in order to make a critical contribution to Portugal's future economic growth and reach into international markets.

The educational network reflects these drives, and aims to be an open international platform which generates a network of multidisciplinary and international knowledge that focuses on people, creating value through the development and demonstration of new ideas in Portugal, to promote scalable living laboratories so as to develop and test these emerging technologies and systems, which our partners, including Portuguese companies, may continuously develop, explore and export worldwide.

The educational programs have brought together a dynamic consortium of universities across Portugal, with the best of MIT educational and research expertise, to create high quality teaching and research. A total of 6 Portuguese universities, 20 Portuguese research centers and national laboratories, together with 25 MIT departments, and all 5 Schools within MIT are involved in this partnership. Altogether 71 new courses have been developed for teaching in the various educational programs, many of which introduce curricular elements novel to Portuguese and to international engineering education. In total, 210 faculty in Portugal and 62 faculty in MIT are involved in this network, which has attracted 425 postgraduate students from 44 countries during its 4 years of existence.

The educational programs provide world class learning opportunities, which address some of today's most pressing scientific, environmental, and socioeconomic challenges. This new approach to post-graduate training goes well beyond conventional natural science or engineering domains. Innovative educational approaches in research and learning enable young participants in this network to explore and understand the economic, social and technical issues that are intrinsic to any management roles they will undertake should they enter industry, and widen the scope of their research and education should they choose academia as their profession.

The global marketplace in which these new leaders will operate is characterized by growing differences between countries and regions, with an increasing importance of markets in newly industrializing

economies, and new powers of knowledge in specific areas. The increasing speed with which goods circulate and market forces evolve has allowed rapid rises in prosperity, but also exposes the global economy to new forms of vulnerability, shocks and crises. For nations to prosper in such a dynamic environment, they should both continually adjust, and also commit themselves to local values and skills – that is, to People, Knowledge, Ideas and Institutions – by connecting themselves to the network of nations and peoples that is shaping the future. This constitutes the major motivation for any international partnership.

2. Doctoral programs

2.1. Bioengineering Systems

2.1.1. Overview

The Bioengineering Systems Doctoral program was designed as an innovative joint Program between three Portuguese Universities: New University of Lisbon – through FCT; University of Minho – through the school of engineering; Technical University of Lisbon – through IST and MIT. It provides teaching and training at the intersection between engineering, life sciences, and innovation. It aims at educating a new generation of leaders in bio-engineering, with a strong emphasis in technical innovation, leadership and systems thinking.

This Program consists of a 1st Year Advanced Studies program, followed by three years of research. The first year is dedicated to educational courses in Innovation of Technological Systems, Bioprocess Engineering, Computational Bio-systems, Cell and Tissue Engineering, Nanobiotechnology, Neurosciences, Drug Development Principles and Biomedical Devices and Technologies. These courses were developed and are taught jointly by faculty from Portuguese Universities and MIT—including some of MIT’s most distinguished professors. They were purposely designed collaboratively by Portuguese and MIT faculty to assure curriculum innovation. During the second semester, the students are involved in extended innovation and entrepreneurship activities (Bio-Teams course) and two nine-week laboratory research rotations, where they initially consider potential bioengineering research areas for their PhD project.

As part of the holistic curriculum, the students travel as a group throughout the Portuguese Universities and live locally to attend the various courses. Bringing faculty and students in contact from across the country serves an integrating function, building strong interactions that lead to more productive and interactive collaborations. Co-teaching provides students with an international view of science, engineering, and research and builds stronger collaborations that are essential for co-supervised thesis projects and collaborative research. The Bio-Teams projects are taught by Portuguese faculty who were trained at MIT for 2-6 months through a “teach-the-teacher” model. Nine Portuguese faculty have been at MIT for this purpose (while also developing research collaboration projects with MIT Faculty).

The remaining 3 years of each student’s doctoral program are dedicated to the development of his/her research work plan within a personal PhD project. A majority of the students choose research projects that are jointly proposed by MIT and Portuguese faculty, and they are hosted by MIT for 12 to 18 months as visiting students performing their collaborative PhD thesis research. Twenty two students of the first two classes of the program (started in 2007 and 2008) have already spent or are currently spending extended time at MIT, and the PhD research areas that were covered together with examples of on-going projects are mentioned below:

A. Stem Cell Bio-Engineering and Regenerative Medicine: 8 students.

Regenerative Medicine aims at improving the length and quality of life by restoring, maintaining, or enhancing tissue and organ function. It merges stem cell research, biomaterials development, and tissue engineering. Some projects in this area aim to demonstrate the feasibility of using human mesenchymal stem cells (MSC) as a source of skeletal muscle cells. The ex-vivo expansion of these cells, followed by differentiation into skeletal muscle cells and their implantation in vivo, represents a promising strategy in clinical settings such as urinary incontinence treatment. Other projects are concerned with the process of cell development, which is tightly regulated and integrates physical and chemical cues from the pluripotent cell to the developed organism. Knowledge of these cues will allow designing Regenerative Medicine approaches to disease. On the tissue engineering/biomaterials development field, the main projects are focused in strategies for controlling the stem cell response to biodegradable polymers through the design of innovative micro/nano-engineered structures and surfaces. Other projects are concerned with the development of modular biosensing platforms (with biocompatible microbeads) to both modulate cell mechanical microenvironment and monitor extracellular proteases.

B. Bioprocess and Biomolecular Engineering: 3 students

This research area includes the development and optimization of bioreactors for the production of recombinant proteins by mammalian and/or stem cells, on the upstream and downstream processes associated with large scale production of plasmid vectors using high-density cell cultures, and on the production of biofuels by fermentation processes. More specifically, the goal of one project is to rationally engineer and test an *Escherichia coli* strain adapted to thrive in high density cell cultures and synthesize the large amounts of supercoiled pDNA required to push the development of pDNA biopharmaceuticals. Another project is focused on the establishment and validation of perfusion bioreactors for cell culture, namely long-term primary culture of alginate encapsulated functional hepatocyte aggregates.

C. Biosystems Innovation, Management and Policy: 3 students

One project in this area addresses the problem of reconciling the needs of product development in tissue engineering with the practices of innovation in healthcare. It is devoted to understand why tissue engineering research and the breadth of solutions explored so far have had limited success in capturing value. It analyzes innovation practices in tissue engineering in order to guide cell-based therapy companies. Another project studies healthcare systems in a hospital environment. It addresses the current opportunities and challenges that computational tools (such as soft computing predictive models) may have in healthcare delivery at Intensive Care Units (ICU), to ultimately predict the outcome of patients under a critical condition, such as septic shock. It is using data from a large Portuguese medical center (Hospital da Luz) in order to validate the analyses and research that are being conducted at the moment.

D. Computational Bioengineering, Genomics, Systems and Synthetic Biology: 2 students

Systems and Synthetic biology are expected to bring major benefits to industrial biotechnology especially in the development of efficient cell factories. A set of mathematical and computational techniques are developed and applied to the problem of designing efficient and informative experiments. In this research area, one current project aims at the optimization of industrial biotechnology processes by identification of kinetic models representing metabolic reactions. It develops a framework for structural reduction and kinetic inference for metabolic networks, which is a promising approach for the construction of dynamic models at the genome scale. Another project is related to the possibility of understanding and controlling stem cell behavior, specifically the problem of generating stem cells from adult somatic cells. The mechanism and role of stochastic effects in that process is studied by building a model of reprogramming at the molecular level.

E. Biomedical Devices and Technologies: Hybrid Human - Machine Systems: 4 students

Hybrid Human-Machine studies are motivated by a desire to better quantify and model human and human-machine performance. Biomedical devices, such as powered ankle-foot prostheses, musculoskeletal loading suits and exoskeletons, and wearable brain sensors, hold promise for medical applications. Two main fields can be defined: one is related to the powered ankle-foot prostheses to help locomotion in patients with neuromuscular disabilities. In this research field, one of the PhD projects aims at the creation of an active ankle foot orthosis for which the problem of portability is no longer an issue. Another project is primarily to design and validate a medical device to support locomotion in individuals with neuromuscular disabilities, through the use of Functional Electrical Stimulation (FES), multi-body dynamics methodologies and control strategies.

The other main field is concerned with wearable devices that are used to record several physiological signals, providing unobtrusive and continuous monitoring. The main challenge in these systems is to develop new recording sensors specially envisioning bioelectric activity detection. One of the PhD Projects proposes to develop an electro-optical fiber-based sensor for bioelectric acquisition specially envisioned for wearable devices. Another one is dedicated to the detection of dysplasia, since it is essential for managing certain types of cancer. Development of a miniaturized spectroscopy system that can be integrated within an endoscopic capsule is underway.

F. Neurosciences (Molecular to Systems Neurobiology and Brain Diseases): 2 students

This research area is related to research mainly in brain diseases, with a close relation to neurobiology and structural biochemistry. One of the projects intends to study the central hypothesis that the molecule cyclin-dependent kinase 5 is a major effector of the NMDA amino acid receptor. Identification of substrates and interactions should help understand the signaling network, whereby neuronal connectivity and brain circuits are regulated. Another project focus on the metabotropic glutamate receptor-dependent long-term depression process at excitatory synapses, which is rapidly becoming recognized as an important form of neuroplasticity in hippocampus, cerebellum, and visual cortex (neural diseases). The studies are performed on a Flailer mouse as a model.

Coordinators of the Bioengineering Systems doctoral program

Bruce Tidor, Department of Electrical Engineering-Computer Science, MIT (PhD director)

Dava Newman, Department of Aeronautics and Astronautics, MIT

Joaquim Cabral, IST, Technical University of Lisbon

Manuel Mota, School of Engineering, University of Minho

Manuel Nunes da Ponte, Faculty of Sciences and Technology, New University of Lisbon (PhD director)

2.1.2. Structure

The structure of the doctoral program in Bioengineering Systems is shown in the table below:

Structure of the doctoral program in Bioengineering Systems

Courses	ECTS	Mandatory/Optional	Semester
Innovation in Technological Systems	6	Mandatory	1st
Bioprocess Engineering	6	Mandatory	1st
Cell & Tissue Engineering	6	Mandatory	1st
Computational Biosystems Science & Engineering	6	Mandatory	1st
Leadership	1	Mandatory	1st
Biomedical Devices and Technologies	6	Optional	1st
Nanobiotechnology and Biomaterials	6	Optional	1st
Neuroscience: Molecular to Systems Neurobiology and Brain Diseases	6	Optional	1st
Principles and Practice of Drug Development	6	Optional	1st
Laboratory rotation I	9	Mandatory	2nd
Laboratory rotation II	9	Mandatory	2nd
Bio-innovation teams with seminar	6	Mandatory	2nd

Each student in the first year follows 6 curricular courses (two weeks each, intensive). Four of these modules are mandatory, while the two remaining requirements are electives from a selection of four courses, which may change from year to year. In addition to the curricular courses the students follow two short-term crosscutting courses (Leadership and Systems thinking), two laboratory placements (9 weeks each) and the Bio-innovation team's seminar.

To complete the first year successfully, the PhD student must obtain for each course a grade no less than 10 (in the 0-20 scale) and a yearly GPA average no less than 14 (out of 20).

At the end of the first semester students may choose from a number of defined research projects, their particular PhD project. The selection process is conducted by the Coordination of Bioengineering but also involves the supervisors and the PIs at both the Portuguese Universities involved and at MIT. If a student is not willing to choose from any of the projects offered, the student must first contact a PT

Faculty Professor/Researcher of the research area of his/her interest, to elaborate a PhD Project to be approved by the Coordination team by the end of the semester.

By September/October (early part of the 2nd Year of the doctoral studies) the student must submit a thesis research plan defined in close collaboration with his/her thesis supervisor. The research plan should provide a brief summary of the context and objectives of the thesis, as well as of the state of the art, hypothesis, research methodology, strategy for the completion of the research and provisional time schedule/tasks calendar. This plan will be considered as part of the formal acceptance process of the student's continuation in the program.

Each qualified PhD student will be assigned a PhD Committee. This committee is responsible for monitoring and guiding the student's progress through his/her research activities. Students should meet with the PhD Committee at least once per semester. Students planning to undertake research at MIT will be required to have an MIT Faculty member on their PhD committee.

During their research work students will be involved in the Doctoral Seminar series presenting their on-going research work.

At the completion of year 2, PhD candidates shall produce a Thesis Progress Report that will be presented both to the Bioengineering Coordination and to the Thesis Committee. If the PhD Committee determines that the student is not making enough progress on his/her research, this will be discussed with the student, and next steps will be determined for further re-evaluation of the thesis working plan.

2.1.3. New courses and faculty involved

For the Bioengineering doctoral program 10 new courses have been specially designed. These courses are taught by 53 faculty members from 7 different Portuguese schools and associate laboratories and by 15 faculty members from MIT. MIT faculty ensures 18% of the teaching (academic year 2010/11).

2.1.4. Use of open-source community-based tools for learning

The students are given access to a website (usually the intranet of one of the home institutions) where most of the class materials are available (syllabus, schedule, PowerPoint presentations, bibliography, home assignments, etc.). The class materials are usually available to students 3-5 days before each course begins. In some courses, where there are guest speakers, the coordinators/responsible faculty supply the class materials by email. In the past, a Moodle page was created and during 2008/2009 academic year the students have used it intensively, but after that year the students lost interest in using this platform. They use Skype and email to communicate with each other and with faculty.

2.1.5. Benchmarking

This section presents program information from selected Bioengineering PhD programs in the US and abroad. Bioengineering and related doctoral degree programs can be found under a number of headings, with related but varied goals: *Bioengineering*; *Biological systems engineering*; *Biological*

chemical engineering; Biomedical engineering; Biomedical and health systems engineering; Biotechnology; and Synthetic Biology. A wide range of programs was scanned for relevant elements. *Bioengineering and Biomedical Engineering* programs, often listed in the same reviews, were found to be most similar to the Bioengineering Systems program. However, *Biomedical* programs differed significantly from Bioengineering Systems in their emphasis on basic medical research. Only one other program, a Master's Degree offered at the University of Melbourne, was found under the designation *Bioengineering Systems*.

The top 20 rankings of 2 lists (*US News and World Report* and *PhDs.org*), were reviewed for this document. In the review were included also top rank Universities outside US, e.g., University of Toronto, Imperial College, ETH, EPFL, TUDelft, among others. Most bioengineering programs have a wide range of choice in elective courses, generally included in Masters Programs curricula - and a narrower focus in specialization. Amongst the programs analyzed, only 3 – Georgia Tech, Dresden/Max Planck and MIT Portugal Program – request students to meet specific core course requirements.

Several of the programs are typically longer than the Bioengineering Systems PhD – 5 to 7 years, however most of them mention the Masters Program as included in the Graduation Program. Some are 4 to 5 years, engaging various strategies towards this economy of time: a Predoc course, preliminary lab rotations, successful completion of a Research Aptitude Exam, and a requirement for prior completion of a Master's degree in bioengineering.

Given the interdisciplinary nature of bioengineering, programs generally involve several departments or schools, or are administered between 2 universities (San Francisco/Berkeley, Harvard/MIT, Rice/Texas Medical Center, etc.).

Concerning extended networking between several Universities, 2 other programs (at Masters level) were detected. The first one involves a network between the Universities of Delft, Leiden, Amsterdam and Rotterdam, in the Netherlands. As stated in program webpage "The program also benefits from the clinical input provided by three teaching hospitals (Leiden, Rotterdam, Amsterdam)". In the same line goes the statement of another network, the Erasmus Mundus Common European Masters Course in Biomedical Engineering, gathering Aachen, Dublin, Ghent, Brussels, Groningen and Prague. The program webpage states, "For a single university it is difficult to have enough knowledge of all specializations in Biomedical Engineering to teach their students on an adequate level". Nevertheless, in none of the previous examples there is collaboration with a University overseas. One distinctive feature of the MIT Portugal Bioengineering Systems program stems from offering resources of collaboration amongst several Portuguese universities, exactly to meet the need for a wide variety of expertise, together with an international collaboration with MIT, including the opportunity to do research at MIT.

Regarding innovation and leadership, apart from the University of Washington Department of Bioengineering program, which states specifically "We invent, patent, license and commercialize at a high rate", apparently there is no other program concerned with innovation, or at least, it is not mentioned, save for the MIT Portugal Program.

Very few universities in the United States, Europe, or Asia offer graduate degree programs that provide at the same time expertise in bioengineering as well as systems understanding and experiences. No peer programs in bioengineering systems were found with courses and structure comparable to this one. None has the same implicit curriculum focus on innovation and leadership, a global view of the field, and industry interface (though opportunities for these areas of development are available). The structure of the Bioengineering Systems PhD, combining the first year course modules, BioTeams, and second semester laboratory placements, is a rather distinctive feature.

The MIT Portugal network was initiated in the context of several state-level and Europe-wide initiatives to link reform of university education to modernization of Europe's economies. Several of the features of this network are highlighted in these initiatives: the improvement of quality in university teaching; the development of a strong knowledge and innovation sector; the strengthening of interdisciplinary university-based research; the promotion of national and international collaboration; fostering research, industry, and government interfaces.

In this context of reform, the vision, scope, and successes of the post-graduate education network are striking. The results are already evident in the development of a research/industry/government interface. In order to build an evidence-based approach to linking university reform with economic modernization, development of benchmarks for state-level, as well as program level, initiatives, is worthy of consideration. Understanding this context of reform also helps to distinguish the goals and unique features of the Bioengineering Systems doctoral program from other Bioengineering post-graduate degree programs.

2.1.6. Student highlights

Daniela Couto, David Malta and Pedro Andrade, PhD students of the class of 2007/2011, have recently launched the start-up Cell2B. In their web site, the new company is described as:

“Cell2B aims to establish itself as a biotechnology company dedicated to the development of a new line of healthcare therapies to prevent and treat organ rejection in patients undergoing organ or tissue transplants. Our therapy has the potential to impact the life of more than 175,000 patients per year in Europe and the USA.”

Pedro Evangelista and Paulo Maia da Silva, PhD students of the class of 2009/2013, are team members of SilicoLife, a start-up “devoted to accelerate strain and bioprocess optimization in Industrial Biotechnology by the use of proprietary computational and modelling tools.”

Daniela and David had extended stays at MIT during the last three years, while Pedro and Paulo have so far performed their research work mostly in Portugal. Although their PhD projects are very different, they all acquired their entrepreneurship drive, skills and gusto during their innovation hands-on approach bio-team course, in their first year of the Bioengineering program.

Eunice Costa enrolled in the bioengineering program in 2007. Her PhD project aims at the development of a modular biosensing platform to both modulate cell mechanical microenvironment and monitor extracellular proteases. Eunice has traveled frequently between Lisbon and Boston, dividing her work

almost equally between labs at MIT and New University of Lisbon. She was recently interviewed for the Chronicle of Higher Education. She stated that she was attracted by a program that "helps you make contacts overseas while letting you keep a foot in your own country."

Cristiana Paulo, PHD student of the class of 2007/2011, developed a non-leaching antimicrobial platform for biomedical devices. Her platform has got an international patent, which was licensed by Matera, a spin-off company of Biocant (Biotechnology park located in Cantanhede). She is motivated to "contributing for the next generation of functional biomaterials that might have impact in human lives". Her work was recently awarded at the international conference in Nanotechnology- TNT2010.

2.1.7. Educational initiatives

Curriculum development

All the educational modules were designed from the beginning, with a close cooperation between Portuguese and MIT Faculty. The educational modules are co-taught: 14 MIT Faculty professors were in Portugal during the educational modules, while 5 were taught by videoconferences.

Training faculty

15 Portuguese faculty stayed for long visiting periods at MIT (2-6 months) where they established research cooperation agreements; and 9 of those, while at MIT, attended the I-Teams course in order to be able to develop/implement the Bio-Teams course and also to engage/interact with the MIT teaching delivery mode.

Special seminars

Each teaching module has a significant number of special seminars (on average around 5 seminars) offered by external faculty from other institutions, or by experts/specialists from industrial affiliates or from other sources, giving our students a broad view of state-of-the-art in the research field, as well as a different view from the industrial and entrepreneurship perspective, that complements the regular educational curriculum.

Workshops

Every year, the Leadership Development module is taught in order to develop/create the leadership skills that this Doctoral Program would like to implement within the students. So far, 4 Leadership Development annual offerings have taken place in Gerês (north of Portugal) with successful feedback from students. Four Business-Government-Academia workshops were organized as annual events that many students attended. The themes covered were: "Emerging Issues and Opportunities in Biopharmaceuticals" (INFARMED, Lisbon; June 11-12, 2007); "Biomedical Devices for 2020" (Braga, May 30-31, 2008); "Challenges in Cell and Gene Therapies" (Coimbra, June 1- 2, 2009); "Personalized Medicine"(Coimbra, June 18, 2010).

Students' general data

Currently there are 75 doctoral students enrolled in Bioengineering Systems, in which 50 of them are already involved in the research work regarding their individual PhD Project. 21 students are expected

to finalize their doctoral studies in September 2011, and some will present their thesis in the final quarter of the current year. Of these students, 13 have had extended research experience at MIT (ranging from 6 to 18 months): their PhD Projects include a strong and valuable cooperation between the Portuguese collaborating institutions and MIT. Since the start of the Program and until February, we have had 22 visiting students at MIT in total, conducting a very important part of their research work plan jointly with Portuguese and MIT faculty supervision and advising.

2.1.8. PhD theses

This section shows the profiles of each student who has spent some period of time at MIT.

The home institution of each student is indicated on the first line as:

IST – Instituto Superior Técnico – Technical University of Lisbon

FCTUNL – Faculty of Sciences and Technology – New University of Lisbon

UMinho – School of Engineering – University of Minho

Ana Lúcia do Rosário	Portugal	BIO	UNL
Starting year 2007	Estimated date of Completion 09/2012	Year of PhD 4 th	Amount of time spent at MIT 19 months
Title of the thesis <i>The role of TAO2 in brain development</i>			

Supervisors

in Portugal: Prof. Margarida Archer (ITQB - UNL)

at MIT: Prof. Li-Huei Tsai (PILM - MIT)

Main Publication

de Anda, FC and **Rosario, AL** *et al.* TAO2 Kinase is Important for Basal Dendrites Formation in the Neocortex. Prepared for submission.

de Rosa, M. *et al* (2010) Crystal structure of a junction between two Z-DNA helices. *PNAS* 107: 20.

Research progress and major scientific contributions

Austim spectrum disorder is a multifactorial heritable development disorder related with disconnectivity. Recently, a novel recurrent microdeletion of chromosome 16p11.2 has been identified that carries substantial susceptibility to autism. One of the genes from the affected region encodes for the protein TAO Kinase 2 (TAO K2). How neurons develop their morphology is an important and challenging question in neurobiology. Little is known about how neurons establish distinct dendrites architectures, specifically if different molecular pathways define the different dendrite compartments, i.e. apical versus basal dendrites in pyramidal neurons, and how those affect connectivity. We have discovered a novel pathway that exclusively affects the formation of basal dendrites but not apical dendrites of pyramidal neurons from the cortex. TAO2 Kinase (t~~h~~ousand-a~~n~~d-o~~n~~e-amino acid 2), an autism spectrum disorder susceptibility protein, plays an essential role in dendrite morphogenesis. TAO2 down-regulation specifically impairs the basal dendrite formation *in vivo*. Moreover, TAO2 interacts with Neuropilin 1 (Npn1), a receptor that binds Semaphorin 3A (Sema3A) and previously associated with basal dendrite morphogenesis. TAO2 over-expression rescued the deficit of dendrite formation in cortical cultured neurons from mice that expresses a Npn1 receptor incapable of binding the secreted Sema3A (*Npn1^{Sema}*). Additionally, TAO2 over-expression rescued the basal dendrite impairment after Npn1 down-regulation *in vivo*. Finally, we found that Sema3A and TAO2 modulate the formation of basal dendrites through the activation of the c-Jun N-Terminal Kinase (JNK). At the moment, the main goal is to determine how TAO2 transduces the activation signaling to the catalytic site through the membrane by X-Ray Crystallography. We hope these results would enable the broadening of available drug targets, not only towards Kinase activation or inhibition, but its regulation.

André Fialho	Portugal	BIO	IST
Starting year 2008	Estimated date of Completion 2012	Year of PhD 3 rd	Amount of time spent at MIT 12 months
Title of the thesis <i>Systems Redesign to Improve the Survival of Shock Patients in ICUs</i>			
Supervisors in Portugal: João Miguel da Costa Sousa at MIT: Stan Finkelstein			
Main Publication			
<p>André S. Fialho, Federico Cismondi, Susana M. Vieira, Joao M.C. Sousa, Shane R. Reti, Michael D. Howell, Stan N. Finkelstein. Predicting outcomes of septic shock patients using feature selection based on soft computing techniques. Applications 13th International Conference, IPMU 2010, Dortmund, Germany, Proceedings, Part II, volume 81 of Communications in Computer and Information Science (CCIS), 65–74. Springer-Verlag Berlin Heidelberg.</p> <p>A. S. Fialho, F. Cismondi, S. Vieira, J. Sousa, S. Reti, M. Howell, R. Welch and S. Finkelstein, “Missing data in large intensive care units databases”. Crit Care Med. 2010; 38: A1-A285</p> <p>Federico Cismondi, André S. Fialho, Susana Vieira, Joao Sousa, Shane Reti, Michael Howell, Stan Finkelstein. Computational intelligence methods for processing misaligned, unevenly sampled time series containing missing data. IEEE Symposium Series on Computational Intelligence, SSCI 2011, Halle aux Farines, Paris, France.</p>			
Research progress and major scientific contributions			
<p>The present work will address a common clinical issue between patients in an intensive care unit (ICU) – <i>Shock</i> – by determining the extent to which variations in the processes of care influence outcome. By using a variety of advanced data mining/analytic techniques, the two main goals of this work will include (1) establish a robust quantitative basis for systems-based interventions to improve outcomes in the ICU shock patients; and (2) develop a reproducible framework for applying the data mining strategies to other healthcare venues.</p> <p>We started by carefully analyzing and pre-processing the data that was previously collected from Beth Israel Deaconess Medical Center, which we found, to contain a large number of variables sampled in different frequencies and segments of absent values. Given that these issues can profoundly bias studies’ results, we proposed a method to (a) align misaligned unevenly sampled data, (b) differentiate absent values related to low sampling frequencies from those resulting of missingness mechanisms, and (c) to classify recoverable and non-recoverable segments of missing data by using soft computing approaches. Simultaneously, we have proposed the application of new knowledge-based methods to a septic shock patient database. The goal was to estimate, as accurately as possible, the outcome (survived or deceased) of these septic shock patients. Results showed that the approaches presented outperformed any previous solutions, specifically in terms of sensitivity. In the near future we plan to use data from a large Portuguese medical center (Hospital da Luz) to "validate" the analyses we are conducting in the moment.</p>			

Carlos Machado	Portugal	BIO	UMinho
Starting year 2007	Estimated date of completion September, 2011	Year of PhD 4 th	Amount of time spent at MIT 7 months

Title of the thesis

Novel modelling formalisms and simulation tools in computational biosystems

Supervisors

in Portugal: Eugénio Ferreira, Isabel Rocha (UMinho)
at MIT: Bruce Tidor

Main Publication

R.S. Costa, **D. Machado**, I. Rocha, and E.C. Ferreira. Critical perspective on the consequences of the limited availability of kinetic data in Metabolic Dynamic Modeling. IET Systems Biology, 2010 (accepted)

R.S. Costa, **D. Machado**, I. Rocha, and E.C. Ferreira. Hybrid dynamic modeling of E. coli central metabolic network combining Michaelis-Menten and approximate kinetic equations. Bio Systems, 2010 (accepted)

R.S. Costa, **D. Machado**, I. Rocha, and E.C. Ferreira. Evaluating the integration of proteomic data for the prediction of intracellular fluxes after knockout experiments. Computer Applications in Biotechnology, 2010 (accepted).

Research progress and major scientific contributions

My initial research reviewed several modeling formalisms currently used in Systems Biology with the goal of finding a suitable formalism for integration of different types of biological networks [1]. The results have shown that Petri nets, being both graph-based and mathematically sound, with several extensions available, are the formalism that offers more flexibility towards this end. They were later used in the development of a framework for structural reduction and kinetic inference for metabolic networks which is a promising approach for the construction of dynamic models at the genome scale [2].

My current work is related with the current gap between dynamic and constraint-based models of metabolism. While the latter only account for stoichiometry, therefore scaling to the genome scale, the former account for concentrations and kinetic parameters, which limits their application to small networks due to limitations in available data. I have explored the influence of kinetic detail from the dynamic formulation in the solution space of the constraint-based formulation. This understanding will allow the estimation of the accuracy of constraint-based solutions.

[1] D. Machado, R.S. Costa, M. Rocha, I. Rocha, B. Tidor, and E.C. Ferreira. A critical review on modelling formalisms and simulation tools in computational biosystems. Distributed Computing, Artificial Intelligence, Bioinformatics, Soft Computing, and Ambient Assisted Living, pages 1063–1070, 2009.

[2] D. Machado, R.S. Costa, M. Rocha, I. Rocha, B. Tidor, and E.C. Ferreira. Model transformation of metabolic networks using a Petri net based framework. International Workshop on Bioprocesses and Petri Nets, 2010.

Daniela Coutinho	Portugal	BIO	UMinho
Starting year	Estimated date of	Year of PhD	Amount of time spent at MIT
2007	Completion	4 th	17 months
	September 2011		
Title of the thesis			
<i>Micro/Nano-processing strategies as tools to clarify the surface mediated biological performance of degradable biomaterials</i>			

Supervisors

in Portugal: Rui Reis (UMinho); Nuno Neves (UMinho); Manuela Gomes (UMinho)
at MIT: Ali Khademhosseini (Harvard-MIT Division of Health Science and Technology)

Main Publication:

Coutinho DF, Shilpa S, Shin H, Oliveira JT, Gomes ME, Neves NM, Khademhosseini A and Reis RL, 2010, Modified Gellan Gum hydrogels with tunable physical and mechanical properties, *Biomaterials*, 31:7494-7502.

Coutinho DF, Costa, P. F., Neves NM, Gomes ME and Reis RL, 2010, Micro and Nano Technology in Tissue Engineering, In *The Tissue Engineering Book: State of the art, Visions and Limitations*, eds. Pallua N, Springer - In Press.

Coutinho DF, Sant S, Shakiba M, Gomes ME, Neves NM, Reis RL, Khademhosseini A, Fabrication of Hydrogel Fiber Bundles from Assembly of Polyelectrolytes, in preparation.

Research progress and major scientific contributions

Biological tissues are composed of functional units, spatially organized and cooperatively orchestrated to perform tissue functions. The milieu of the tissue microenvironment consists on the assembly of micro- and nano-sized entities organized in three dimensional (3D) structures. However, this accurately defined organization is specific to each tissue, resulting in dramatically inhomogeneous microenvironments throughout the human body. Engineered biological tissues should be customizable, thus increasing their potential clinical impact. However, most of the existing engineered systems fail to replicate simultaneously the architecture of the tissues and the physical and chemical cues provided by the microenvironment. Because of their unique similarity with the extracellular matrix (ECM) highly hydrated structure, hydrogels are very useful for the local delivery of encapsulated cells, enhancing tissue function. Hydrogels may be specifically designed to be photosensitive, enabling shaping the hydrogel according to the specific tissue microarchitecture. The aim of this work was to develop a hydrogel with enhanced properties and to engineer it with micro-features and biochemical cues, relevant for tissue engineering applications. Gellan gum, a hydrogel approved by FDA for food industry, was functionalized with double bonds, making it responsive to ultraviolet light. The physical and mechanical properties of the developed hydrogel can be easily tuned by varying the parameters of the cross-linking mechanisms, allowing it to be used in a variety of applications. 3D encapsulation of fibroblast cells in the polymer networks demonstrated in vitro cytocompatibility confirmed by high cell viability. The overall performance of the hydrogel can be fine-tuned by combining polymers with complementary characteristics. As a proof of concept, polycation chitosan was combined with the anionic methacrylated gellan gum. The resulting polyelectrolyte hydrogel was micro-processed into bundles of fibers aimed at mimicking the natural architecture of collagen fibers. The biological functionality of the matrices was further enhanced by covalently incorporating RGD motifs into the photocrosslinkable polymer backbone. Encapsulated cells exhibited good viability and alignment. The new functionalized hydrogel was micro-processed into a fiber bundle system that closely models both the natural architecture and biochemical microenvironment of collagen fibers.

Daniela Couto	Portugal	BIO	IST
Starting year 2007	Estimated date of Completion October 2011	Year of PhD 4 th	Amount of time spent at MIT 18 months

Title of the thesis

Opportunities Arising at the Intersection of Technologies in Healthcare

Supervisors

in Portugal: Manuel Heitor (IST), Joaquim Sampaio Cabral (IST), Pedro Saraiva (Universidade de Coimbra)

at MIT: Charles Cooney (MIT), Luis Perez-Breva (MIT)

Main Publication

Couto D. S., Perez-Breva L., Cooney C.L.. “Reinventing regenerative medicine by learning from past examples”, Submitted to Nature Drug Reviews

Research progress and major scientific contributions

Tissue engineering and regenerative medicine products have showed great potential and strong financial support, but have had limited success in capturing value since the early 1990s. Despite the uptake in tissue engineering research and the breath of solutions explored few advances have progress to clinical stage. We hypothesize that the reason for limited success of tissue engineering is rooted in the challenges to reconcile the needs of product development and business strategy specific to tissue engineering with the practices of innovation in healthcare.

We propose to identify and address these challenges with the study of innovation practices in tissue engineering, including technological development, regulatory approval process, and mechanisms of market regulation. The study will build from previous lessons from two distinct areas – regenerative medicine and combination products. We approach tissue engineering simultaneously as a combination product and a cell-based therapy.

Research completed at to this point looked into three main aspects of cell-based therapies and combination products. Recently, we identified past attempts at capturing value by regenerative medicine companies that illustrate the co-evolution of business strategy and technology. We developed a new framework to guide the cell-based therapies companies in co-evolving business strategy with technological development in a dynamic environment for financing and regulation. Finally, we also explored the historical evolution and the dynamics of innovation in combination products from the technological, corporate, and regulatory vantage points.

This thesis aims to bring three key contributions to the scientific literature. First, understand the co-evolution of business strategy and technology in the strategy of regenerative medicine companies. Second, assess and discuss the differences in the innovation process for combination products and single products including drugs, biologics, or medical devices. Third, propose mechanisms to evolve and accelerate the innovation practices in emergent areas of healthcare, such as tissue engineering.

David Braga Malta	Portugal	BIO	IST
Starting year 2007	Estimated date of completion September 2011	Year of PhD 4 th	Amount of time spent at MIT 24 months
Title of the thesis <i>High-throughput Ex-vivo Engineered Combinatorial μ-Niches - From the Pluripotent to the Differentiated Cell</i>			
Supervisors in Portugal: Cláudia Lobato da Silva and Joaquim Sampaio Cabral at MIT: Sangeeta N. Bhatia			
Research progress and major scientific contributions			
<p>Development is a tightly regulated process that integrates physical and chemical cues from the pluripotent cell to the developed organism. These cues trigger an orchestrated cascade of molecular and cellular events culminating in cellular and tissue organization. Understanding these mechanisms is the basis of Regenerative Medicine. The knowledge of what determines these coordinated events will allow designing Regenerative Medicine approaches to disease. Several studies have looked at the role of chemical and physical cues in development and a deep understanding of this orchestration of factors, which combines inputs from several sources into a single cellular fate, is missing. Several technological platforms have been developed to study chemical cues (e.g. growth factors and cytokines), but there is a general lack of knowledge and appropriate tools to study either the physical cues (extracellular matrix (ECM)) or their combined presentation with chemical cues.</p> <p>With this objective in mind we developed a combinatorial platform to study the cellular niche, by controlling both physical and chemical cues in a high-throughput combinatorial manner. We developed an ECM array comprising all the pair wise combinations of commercially available ECM molecules. Using micro-printing technology we created an array of 4000 μ-niches in a single microscopy slide. To achieve the level of biological complexity, we adapted the previous technology to a 96 well format enabling the integration of the ECM array with small molecule libraries and thus achieving the combinatorial environment that cells are exposed to.</p> <p>Using the technologies described we were able to study development at different discreet points, mapping the journey from the pluripotent to the differentiated cell states. Starting at the pluripotent cell we identified ECM combinations that promote self-renewal of these cells, such as Collagen II when co-presented with Nidogen-1. The pluripotent cell then undergoes a process of specification. In the liver's case, besides all the chemical cues already known, this work allowed clarifying the role of ECM on liver versus pancreas specification in particular the role of fibronectin and merosin. This ECM combination appears to promote differentiation of cells towards the liver lineage regardless of the chemical cue that is presented. Finally, in the adult bone marrow, ECM has a critical role on mesenchymal stem cell fate. Here we could elucidate that different ECM combination trigger different cellular fates. For instance, elastin in combination with decorin promotes cellular adhesion whereas elastin when presented with nidogen-2 promotes cellular proliferation.</p>			

Débora Ferreira	Portugal	BIO	UMinho
Starting year 2007	Estimated date of Completion 10/2011	Year of PhD 4 th	Amount of time spent at MIT 12 months

Title of the thesis

New Functions of the Endoscopic Capsule

Supervisors

in Portugal: Graça Minas, José Higinio Correia
at MIT: Michael S. Feld (deceased)

Main Publication

D. S. Ferreira, J. Mirkovic, R. F. Wolffenbuttel, J. H. Correia, and G. Minas, "Diffuse-reflectance spectroscopy for integration in endoscopic capsules to assess esophageal tissue," *Journal of Optics* (2011). *Submitted*

D. S. Ferreira, J. H. Correia, and G. Minas, "Spectroscopy for the detection of esophageal dysplasia using optical microsensors for integration in endoscopic capsules," *IEEE Transactions on Biomedical Engineering* (2011). *Submitted*

Research progress and major scientific contributions

Detection of dysplasia is essential for managing gastrointestinal cancer since the chances of an effective treatment increase if the disease is diagnosed at an early stage, significantly improving the survival rate. However, dysplastic lesions are difficult to identify by visual inspection during routine endoscopy.

Optical techniques, such as diffuse reflectance and fluorescence spectroscopy, may overcome some limitations of current screening methods and considerably improve the ability to detect dysplasia as they have the potential to provide biochemical and morphological information of normal and diseased tissue.

The development of a miniaturized spectroscopy system that can be integrated within an endoscopic capsule will have a huge clinical utility in the medical devices field, since it will add essential diagnostic functions as a complement to current capsule imaging functions. The designed system has unique features (small size, low-cost, low-complexity, same throughput of conventional systems), and is based on thin-film optical filters and silicon photodiodes for the selection and detection of different spectral bands significant for diagnosis.

In this project, a strategy for spectroscopy tissue diagnosis using a small number of --wavelengths was developed. The feasibility to accurately quantify tissue information using only 16 wavelengths was demonstrated using a spectroscopic esophageal data set. These results were an important step for the development of a miniaturized spectroscopy system to be integrated in endoscopic capsules. The designed system includes UV and white-light LEDs for illumination and 16 high-selective optical detectors, designed for specific wavelengths. The optical detectors are based on thin-film optical filters and silicon photodiodes. The optical filters were fabricated and its spectral performance was shown to be sufficient to be used as a tool to aid in diagnosis.

Eunice Costa	Portugal	BIO	FCTUNL
Starting year 2007	Estimated date of Completion 09/2011	Year of PhD 4 th	Amount of time spent at MIT 13 months

Title of the thesis

Bioactive Beads for Local Modulation and Sensing of Cell Mechanical Environment in 3D Engineered Tissues

Supervisors

in Portugal: Ana Aguiar Ricardo, FCTUNL
at MIT: Paula T Hammond and Linda G Griffith

Main Publication

Costa, E., Coelho, M., Ilharco, L. M., Aguiar-Ricardo, A., Hammond, P. T. Tannic Acid Mediated Suppression of PNIPAAm Microgels Thermoresponsive Behavior, *Macromolecules* **2010**, *44*, 612.

Costa, E., de-Carvalho, J., Casimiro, T., Lobato da Silva, C., Cidade, M.T., Aguiar-Ricardo, A. Tailoring Thermoresponsive Microbeads in Supercritical Carbon dioxide for Biomedical Applications, in press, *J Supercrit. Fluid.* **2010**, DOI: 10.1016/j.supflu.2010.10.039.

Serra, M., Brito, C., **Costa, E.M.**, Alves, P. Integrating human stem cell expansion and neuronal differentiation in bioreactors. *BMC Biotechnol.* **2009**, *9*, 82.

Research progress and major scientific contributions

Several human diseases, such as cancer or arthritis, are associated with deranged tissue mechanical microenvironment associated with unregulated cell-secreted proteases function. The success of protease-based therapies has been hindered by an ill-defined understanding of the complex regulatory networks in which extracellular proteases are involved. The project concerns the development of a modular biosensing platform to both modulate cell mechanical microenvironment and monitor extracellular proteases. For that purpose biocompatible and thermo-responsive poly (*N*-isopropylacrylamide) (PNIPAAm) micro-beads with well-defined morphology were successfully prepared using a green synthesis approach by polymerization in supercritical carbon dioxide. The mechanical properties of these beads were systematically modified by using different cross-linking species. Furthermore NIPAAm was also copolymerized with other monomers, namely methacrylic acid (MAA), to render both pH and temperature responsive PNIPAAm-PMAA micro-beads and allow further functionalization. A layer-by-layer polymer assembly strategy has been studied for both creating cell-interactive surface coatings and incorporating fluorogenic substrates for proteases. The interaction of different polymers with PNIPAAm beads has an impact on their morphology and thermo-responsive behavior, as it was demonstrated for the complexation of tannic acid (TA). The reversible hydrogen bonding between TA and PNIPAAm beads allowed the preparation of micro-gels which morphology and temperature response depended on pH and TA content. Currently, several cell-adhesive polymer pairs such as poly (L-lysine) and poly (glutamic acid) or poly (allylamine hydrochloride) and poly (acrylic acid) are being successfully explored for coating PNIPAAm-PMAA micro-beads and possibly create diffusional barriers to increase protease specificity or sensitivity. The behavior of the bioactive sensing micro-beads will be examined in 3D tissue cultures under conditions that are expected to result in diverse protease profiles, mimicking healthy and diseased tissues.

Federico Cismondi	Argentina	BIO	IST
Starting year 2008	Estimated date of Completion August 2012	Year of PhD 3 rd	Amount of time spent at MIT 12 months

Title of the thesis

Modeling High-Dimensional Clinical Data Sets for Prediction and Intervention

Supervisors

in Portugal: Joao Miguel da Costa Sousa (IST)
at MIT: Stan Finkelstein

Main Publication

Federico Cismondi, André S. Fialho, Susana Vieira, Joao Sousa, Shane Reti, Michael Howell, Stan Finkelstein. Computational intelligence methods for processing misaligned, unevenly sampled time series containing missing data. IEEE Symposium Series on Computational Intelligence, SSCI 2011, Halle aux Farines, Paris, France.

André S. Fialho, **Federico Cismondi**, Susana M. Vieira, Joao M.C. Sousa, Shane R. Reti, Michael D. Howell, Stan N. Finkelstein. Predicting outcomes of septic shock patients using feature selection based on soft computing techniques. Applications 13th International Conference, IPMU 2010, Dortmund, Germany, Proceedings, Part II, volume 81 of Communications in Computer and Information Science (CCIS), 65–74. Springer-Verlag Berlin Heidelberg.

Abigail L. Horn, **Federico Cismondi**, André S. Fialho, Susana M. Vieira, Joao M.C. Sousa, Shane Reti, Michael Howell, Stan Finkelstein . Multi-Objective Performance Evaluation Using Fuzzy Criteria: Increasing Sensitivity Prediction for Outcome of Septic Shock Patients. 18th World Congress of the International Federation of Automatic Control (IFAC), Milano, Italy, 2011.

Research progress and major scientific contributions

During my PhD project I started by exploring the current opportunities and challenges that computational tools (such as soft computing predictive models) may have in healthcare delivery at the Intensive Care Unit (ICU), and then present an specific application of how some of these tools (e.g. neural networks and fuzzy systems) may allow to classify and ultimately predict the outcome of patients under a critical condition such as septic shock. I am currently working in the prediction/classification of the usefulness of additional lab testing in ICU patients. Our team hypothesized that it would be possible to reduce the amount of lab testing in patients for which new tests do not add useful information to change the treatment strategy. This reduction, performed by correctly classifying and eliminating those tests that would have no significant variations when compared to previous results, could be both a source of a reduction in morbidity and hospitalization costs. An ICU database collected at Beth Israel Deaconess Medical Center, containing data of 26,665 patients, was used for modeling purposes. Proposed models will be validated with a database collected at Hospital da Luz from Lisbon, Portugal. Between the major contributions of my research it can be pointed out:

- the reduction in patients' morbidity/mortality due to excessive lab testing,
- the reduction in hospital costs due to excessive lab testing.

Filipe Grácio	Portugal	BIO	IST
Starting year 2008	Estimated date of Completion August 2012	Year of PhD 3 rd	Amount of time spent at MIT 18 months

Title of the thesis

Understanding and controlling stochasticity in cellular reprogramming

Supervisors

in Portugal: Joaquim Sampaio Cabral
at MIT: Bruce Tidor

References of the three best publications on PhD research

In preparation.

Filipe Gracio, Joaquim Cabral, Bruce Tidor. Modeling of Stem Cell Generation Protocols: Stochasticity deconstructed.

Research progress and major scientific contributions

In this work we analyze the debate surrounding the proposed Elite and Stochastic models of stem cell reprogramming and look at ways to gain insight into the mechanism of the process. We build mass action models of the core circuitry of the stem cell pluripotency: the model includes not only the NANOG, OCT4, SOX2 network, but also important epigenetic regulatory features. We are able to show that the network topology reported in the literature is consistent with the observed experimental behavior of bistability and inducibility. Based on simulations of stem cell generation protocols we show that cooperative and independent reaction mechanisms have experimental identifiable differences and we analyze such differences and their biological explanations. We also argue that Stochastic and Elite models of Stem Cell generation need not represent any fundamental biological difference but rather just the amount of information we have about the distribution of cellular states before and during the reprogramming protocols. We show that unpredictability decreases as the cell moves through the necessary changes, and that identifiable groups of cells with elite-like behavior can come about by stochastic process. We also show how different mechanisms and kinetic properties impact the prospects of improving the efficiency of iPSC generation protocols.

Geisa Gonçalves	Brazil	BIO	IST
Starting year 2008	Estimated date of Completion September 2012	Year of PhD 3 rd	Amount of time spent at MIT 16 months
Title of the thesis <i>Rational Engineering of E. coli strains for improved manufacturing of plasmid biopharmaceuticals</i>			

Supervisors

in Portugal: Miguel Prazeres and Gabriel Monteiro

at MIT: Kristala Prather

Research progress and major scientific contributions

The use of plasmid DNA (pDNA) as a biopharmaceutical has been gaining momentum over the last years with the approval of the first DNA vaccines. The goal of my project is to rationally engineer and test an *Escherichia coli* strain specifically adapted to thrive in high density cell cultures and synthesize the large amounts of supercoiled pDNA required to push the development of pDNA biopharmaceuticals. Most *E. coli* host strains used to produce pDNA were originally mutated to facilitate cloning and production of recombinant proteins and thus may not be optimal for pDNA production. In order to understand the role and interplay of specific sets of genes on *E. coli* metabolism and pDNA synthesis it is important to analyze the knockout and over expression of key genes on wild-type *E. coli* and on multi-mutated strains such as DH5 α . With the goal of high pDNA production in mind, we set out to enhance the production of nucleotides by systematically mutating key genes in wild type (MG1655endA-recA) and genetically modified (DH5 α) strains. Specifically, the pykF and pykA genes in the glycolysis pathway were knocked out and the rpiA gene in the pentose phosphate pathway was over-expressed. Twenty four strains have been already constructed using different combinations of gene knockouts (pykF, pykA, recA, endA) and over expressed genes (rpiA). Gene knockouts were done using the P1 transduction (C. Martin and S.-H. Yoon, 2009) and gene inactivation (S.-H. Yoon and K. Solomon, 2009) protocols. Gene over expression was done using promoter replacement protocol (S.-H. Yoon and K. Solomon, 2009). Shake flask tests were carried out with these strains using two different carbon sources, glycerol and glucose. Higher production of pDNA and biomass and lower acetic acid formation were observed in glycerol medium for all tested strains. Preliminary results show that the mutated strains such as DH5 α pykF-, DH5 α pykF-pykA- and MG1655endA-pykF-pykA-recA- produce twice as much plasmid when compared with the wild MG1655 and DH5 α in shake flask and are therefore potentially high pDNA producers. The impact of mutations on the rpiA gene was not evaluated yet. Large-scale tests are also necessary to confirm the data from shake flask experiments. Additionally, the impact of the new strains on the downstream processing will be analyzed. The results obtained thus far are encouraging and will hopefully represent an important contribution to the field of plasmid biopharmaceuticals.

Isa P. Monteiro	Portugal	BIO	UMinho
Starting year 2007	Estimated date of Completion End of 2011	Year of PhD 4 th	Amount of time spent at MIT 14 months

Title of the thesis

Development of a novel Regenerative Medicine Approach to treat Skin Defects

Supervisors

in Portugal: Alexandra P. Marques and Rui L. Reis, UMinho
at MIT: Robert S. Langer and Daniel S. Kohane

Research progress and major scientific contributions

Skin is the largest organ in the human body; it constitutes a protective barrier from the outside environment and prevents dehydration. Skin replacement is necessary for the treatment of burns, venous or pressure ulcers and after amputation or excision of tumors. In the case of full-thickness skin defects, skin regeneration using a Tissue Engineering approach suggests the need for a skin-like construct, which aims to restore both epidermal and dermal components of the human skin.

This PhD work focuses on the combination of biocompatible natural-based polymeric scaffolds with primary and/or stem cells in order to create *in vitro* three dimensional epidermal-dermal substitutes that would be able to overcome some of the drawbacks of the skin substitutes currently used in clinical practice

Hyaluronan (HA) is a natural compound of the extra-cellular matrix that provides a permissive environment for regeneration rather than healing through scarring and fibrosis. HA was selected to produce porous scaffolds aimed at creating the dermal component of the skin substitutes. One of the major problems of large area skin defects is the lack of vascularization. In an attempt to overcome this problem, angiogenic factors were encapsulated in liposomes and microparticles, which were then incorporated in the HA dermal scaffold. The sustained release of these factors is expected to conduct microvasculature formation, both by the differentiation of stem cells that can also be seeded within the porous structure and by the recruitment of endothelial progenitor cells from the neighborhood of the damaged tissue.

The epidermal component was either created by using a HA gel or by applying the spray-assisted layer-by-layer (LbL) technique to produce a polyelectrolyte multilayer of HA and poly-L-lysine on the top of the HA porous scaffold (dermal component). This innovative processing methodology allowed the creation of distinct layers with distinct physical-chemical-biological properties. The LbL technique was also used to entrap growth factors, namely epidermal growth factor, in order to promote epidermal regeneration and to allow for controlled and sustained release through surface erosion of the film.

Co-cultures were obtained by seeding different cells in different regions of the scaffold. Epidermal regeneration was achieved by the differentiation of human amniotic fluid stem cells and adult bulge stem cells (mild-telogen) into the epidermal lineage and culturing them in the epidermal component of the scaffold. The functionality of the proposed approaches will be assessed in burn and excision mouse and rat models.

Isabel Ferreira	Portugal	BIO	IST
Starting year 2007	Estimated date of Completion September , 2011	Year of PhD 4 th	Amount of time spent at MIT 5 months

Title of the thesis

Bioprocess Engineering on Microbial Desulfurization: Cell Immobilization and Cell Recycle for Desulfurization of Crude oil

Supervisors

in Portugal: Maria Raquel Múrias dos Santos Aires de Barros, IST
Carla da Conceição Caramujo Rocha de Carvalho, IST
at MIT: Professor Daniel I. C. Wang

Research progress and major scientific contributions

In 2009, the crude oil demand in the world was *c.a.* 84 millions of barrels per day, generating around US\$ 6 billion. During transformation and use of crude oil derivatives e.g. diesel and gasoline, aromatic and sulfur-containing toxic compounds are formed and released. Consequently regulatory agencies have been limiting the total amount of compounds such as sulfur. Petroleum companies are using hydro-desulfurization, an expensive chemical process, able to transform sulfur compounds into H₂S but that is often ineffective when eliminating some complex organic compounds such as benzothiophenes. Bio-desulfurization, BDS, offers a sustainable and less expensive biological way to eliminate sulfur containing compounds from crude oil. In this work, BDS of dibenzothiophene (DBT), the most common sulfur compound present in crude oil was tested with *Rhodococcus erythropolis* IGTS8 and *R. erythropolis* DCL14. Experiments were performed in both aqueous, aqueous-organic and aqueous-crude oil biphasic systems. In aqueous phase systems, the cells were able to fully metabolize 0.1 mM DBT but higher concentrations were prevented due to DBT'S low water solubility. Hence, several *n*-alkanes were tested to assess their use as DBT reservoir and toxicity upon *R. erythropolis* whole cells. Hexadecane proved to be one of the best solvents: at an initial DBT concentration of 10 mM, IGTS8 and DCL14 cells metabolized 7.9 mM and 3 mM of DBT in just 48 hours, respectively. Cell immobilization was also tested, but the supports investigated did not significantly improve the cells' BDS rate. Free cells of both strains were used in order to evaluate their crude oil BDS capability. Results showed that cells can maintain viability in direct contact with crude oil for at least 3 months and that are able to metabolize DBT present in the oil. At this moment, experiments on cell adaptation to sulfur toxic compounds in order to improve BDS rate are in place and a process scale up is foreseen.

The results obtained prove the feasibility of using bacterial cells to remove sulfur from crude oil. In that way, this work has contributed for the use of a cleaner source of energy leading to a future improvement of society's health. The outcome of my research has been presented in international congresses in the form of both oral and poster communications.

João Guerreiro	Portugal	BIO	IST
Starting date 2007	Estimated date of completion 2011	Year of PhD 4 th	Amount of time spent at MIT 24 months

Title of the thesis

Skeletal Muscle Differentiation of Human Mesenchymal Stem Cells (MSC) for Therapeutic Applications

Supervisors

in Portugal: Cláudia Lobato da Silva (IST), Joaquim Sampaio Cabral (IST)
 at MIT: Daniel Griffith Anderson, Robert S. Langer

Main Publication

De Sousa FB, **Guerreiro JDT**, Ma M, et al. Photo-response behavior of electrospun nanofibers based on spiropyran-cyclodextrin modified polymer. *J. Mater. Chem.* 2010; 20(44):9910-9917.

Research progress and major scientific contributions

Adult mesenchymal stem cells (MSC) present high proliferation potential in vitro and are able to differentiate into diverse lineages, while display low immunogenic and intrinsic immunomodulatory characteristics. These properties make them the ideal target for therapeutic applications. They can be used directly as undifferentiated cells or after differentiation into a specific lineage. One lineage of mesenchymal origin not fully studied, but of great interest is the skeletal muscle. These cells are responsible for the correct function of different organs. The ex-vivo expansion of MSC followed by differentiation into skeletal muscle cells and their implantation in vivo would represent a promising strategy in clinical settings such as urinary incontinence treatment for which the application of myoblasts have been shown to restore the organ function, though with moderate success.

In order to explore this hypothesis with a therapeutic application as an endpoint, three different approaches are being pursued in which MSC from both bone marrow (BM) and adipose tissue (AT) are used.

- Gene Transfection - Both BM and AT MSC were transfected with plasmids containing myogenic relevant genes that could putatively shift their fate into the skeletal muscle lineage. The nonviral transfection *via* Poly(β -amino esters) (PBAE) nanoparticles was optimized for the cell types in study and under different serum conditions with an eGFP-codifying plasmid. Some conditions showed a genetic profile consistent with myogenic differentiation, though the stimuli were not sufficient to promote clear myogenic differentiation. Microporation is currently being employed as a transfection platform as it has showed to be able to yield higher transfection rates.
- Physical Cues – The use of nanofibers as a support for myogenic differentiation was previously reported (Dang, 2007). Such approach led to some preliminary promising results and is currently being further explored by combining synthetic polymers and extracellular matrix components as a scaffold to support cell adhesion and growth/differentiation.
- Chemical Cues – Several chemical molecules reported in the literature for having a positive impact in myogenic differentiation (both small molecules and medium cocktails) were tested but did not show significant myogenic differentiation induction to AT or BM MSC.

Mariana Fernandes	Portugal	BIO	UMinho
Starting year 2007	Estimated date of Completion 09/2011	Year of PhD 4 th	Amount of time spent at MIT 7 months

Title of the thesis

Wearable Brain Cap

Supervisors

in Portugal: Paulo Mendes (UMinho) and J. Higinio Correia (UMinho)
at MIT: Rajeev Ram (MIT)

Main Publication

M. Fernandes, N. S. Dias, A. F. Silva, J. S. Nunes, S. Lanceros-Méndez, J. H. Correia and P. M. Mendes, "Hydrogel-based photonic sensor for a biopotential wearable recording system," *Biosensors and Bioelectronics*, vol. 26 (1), pp. 80-86, 2010.

M. Fernandes, K.S. Lee, R. J. Ram, J. H. Correia and P. M. Mendes, "Flexible PDMS -based dry electrodes for electro-optic acquisition of ECG signals in wearable devices", 32nd Annual International Conference of the IEEE Engineering in Medicine and Biology Society, Buenos Aires, Argentina, 31 August - 4 September, 2010.

M. Fernandes, J. H. Correia and P. M. Mendes, "Electro-optic acquisition system for ECG wearable sensor applications", *IEEE Transactions on Biomedical Circuits and Systems*, submitted.

Research progress and major scientific contributions

Wearable devices are used to record several physiological signals, providing unobtrusive and continuous monitoring. The challenge in these systems is to develop new recording sensors specially envisioning bioelectric activity detection. The existent devices are difficult to integrate mainly due to the amount of electrical wires and components needed. Optical techniques, based on optical fibers, can provide easy integration into textiles and other wearable materials. Furthermore, optical sensors are immune to electromagnetic interference, resistant to harsh environments, and electrical wire free. This work proposes an optical fiber-based sensor for bioelectric acquisition specially envisioned for wearable devices. The effect behind the EO acquisition of biopotentials is the EO effect, which refers to changes in the refractive index of a material and its effect on polarized light, induced by the application of an external electric field. The main functional stages of this sensor are: optical signal generation; control and modulation; and detection. The system includes a Lithium Niobate Mach-Zehnder Interferometer (MZI) Modulator as the sensing element, and a signal conversion and processing stage. We have developed theoretical models for electro-optic acquisition of bioelectric signals, as well as simulations using proper optical software, to fully characterize and test the proposed system. Experiments were performed to validate the electro-optic acquisition system in terms of signal amplification and quality, stability and frequency response. A light source with an optical power of 10 μ W and with a wavelength operation of 1530-1565 nm was used. The modulated intensity is amplified and converted to an output voltage with a transimpedance gain of 5x10⁵ V/A, producing a voltage amplification of 10 V/V. Results were compared with a standard bioelectric signal acquisition using an instrumentation amplifier. It was demonstrated that the performance of the overall system was adequate and in conformity with the simulations, showing good magnitudes, frequency response and noise and interference reduction. In addition, bioelectric signals such as Electrocardiogram (ECG), Electromyogram (EMG) and Electroencephalogram (EEG) were successfully acquired. As a final remark, the electro-optic sensor herein described allows to develop truly wearable bioelectric monitoring solutions.

Paulo Melo	Portugal	BIO	IST
Starting year 2009	Estimated date of completion 2012	Year of PhD 2 nd	Amount of time spent at MIT 6 months

Title of the thesis

Development of a functional electrical stimulation system prototype to aid locomotion in individuals with motor impairments

Supervisors

in Portugal: Miguel Tavares Da Silva and Jorge M. Martins
at MIT: Dava J. Newman

Main Publication

Melo, P.L., Silva, M.T., Martins, J.M., Newman, Validation Procedure for a Multibody Dynamics Model of the Human Leg and Foot for Functional Electrical Stimulation Actuation and Control, *The 1st Joint International Conference on Multibody System Dynamics*, May 25-27, 2010, Lappeenranta, Finland.

Malcata, R., Silva, M.T., Martins, J., **Melo, P.L.**, Costa, João, Development of a Control Architecture for a Musculoskeletal Model of a Human Ankle Joint Using Multibody Dynamics and Hill-Type Muscle Actuators, *The 1st Joint International Conference on Multibody System Dynamics*, May 25-27, 2010, Lappeenranta, Finland.

P.L. Melo, C.F. Vasconcelos, J.M. Martins, M.T. Silva, Desenvolvimento de uma Ortótese Tornozelo-Pé com Actuação Híbrida para Apoio à Locomoção, *4^o Congresso Nacional de Biomecânica*, 4-5 February, 2011, Coimbra, Portugal.

Research progress and major scientific contributions

The objective of this project is to devise and validate a medical device to support locomotion in individuals with neuromuscular disabilities, through the use of Functional Electrical Stimulation (FES), multibody dynamics methodologies and control strategies. The device will promote locomotion and rehabilitation of the lower limbs' musculoskeletal apparatus, in individuals with impaired mobility resulting from neurological conditions such as stroke or spinal cord injury. The prototype comprises a closed loop network of sensors and actuators. Since there are no muscle stimulators in the market able to be embedded in closed loop systems, a small portable custom muscle stimulator was built. The device architecture includes four individualized stimulation channels (actuators) and a modular design, which means that the amount of actuators can go from one to four, depending on user's pathology. The device enables complete customization of the stimulation parameters and was designed to output symmetric biphasic electrical pulses. This type of output allows an equal charge distribution at the user's stimulation site, preventing skin damage over long stimulation periods. Inertial Measurement Units (IMUs) have been integrated within the stimulation loop to provide feedback on specific joint angles. Preliminary results show that the width of the stimulus pulse can be used as the main variable to control the degree to which the foot dorsiflexes. Using this system, trials are to be performed so that a muscle model is identified, accounting for the muscles' kinematics and contraction dynamics. This information will allow the design of the FES control architecture. The actuator will generate the required electrical pulse sequences, according to the muscle identification algorithm and to an adaptive closed loop control law. The final system will be used by patients on a daily basis, but will also serve as a rehabilitation tool.

Rui Tostoes	Portugal	BIO	FCTUNL
Sezin ADAY	TURKEY	BIO	IST
Starting year 2007	Estimated date of Completion October 2011	Year of PhD 4 th	Amount of time spent at MIT 1.5 months
Title of the thesis <i>Multicellular human hepatocyte spheroids, cultured in perfusion bioreactor, as a novel valuable tool for long-term in vitro drug induction tests</i>			

Supervisors

in Portugal: Dr Paula Alves, Professor Manuel Carrondo
at MIT: Professor DIC Wang

Main Publication

Perfusion of 3D encapsulated hepatocytes--a synergistic effect enhancing long-term functionality in bioreactors. **Tostões RM**, Leite SB, Miranda JP, Sousa M, Wang DI, Carrondo MJ, Alves PM. *Biotechnol Bioeng.* 2011 Jan;108(1):41-9.PMID: 20812261

Improving expansion of pluripotent human embryonic stem cells in perfused bioreactors through oxygen control. Serra M, Brito C, Sousa MF, Jensen J, **Tostões R**, Clemente J, Strehl R, Hyllner J, Carrondo MJ, Alves PM. *J Biotechnol.* 2010 Aug 2; 148(4):208-15. Epub 2010 Jun 17.PMID: 20600380

Extending hepatocyte functionality for drug-testing applications using high-viscosity alginate-encapsulated three-dimensional cultures in bioreactors. Miranda JP, Rodrigues A, **Tostões RM**, Leite S, Zimmerman H, Carrondo MJ, Alves PM. *Tissue Eng Part C Methods.* 2010 Dec; 16(6):1223-32. Epub 2010 Apr 6.PMID: 20184401

Research progress and major scientific contributions

Maintaining the phenotype of human hepatocytes in long term cultures is a yet unmet need; in this work, we have assembled and validated a bioreactor perfusion system to allow long term culture of functional human hepatocytes; due to its easy sampling, it is possible to follow the time course of an hepatocyte population subject to any hepatotoxic agent and test short term drug interactions (such as CYP450 induction) in a higher throughput format by taking a larger sample and sub culturing it in microtiter plates.

For the last 20 years a considerable amount of literature was published suggesting that 3D primary cultures of hepatocytes outperform 2D culture methods. However, these studies are mostly made using rat hepatocytes and the response of the cells to typical CYP450 inducers (phase I enzymes) is only maintained for approximately 1 week. Human hepatocytes, cultured as spheroids (<200 µm diameter) in a fully controlled perfusion bioreactor with easy sampling (working volume 300 ml), maintained Albumin production up to 30 days and CYP450 activity (measured by ECOD biotransformation and gene expression analysis) was inducible up to 2 weeks. Cytokeratin-18, Albumin and CYP450 3A were detected by confocal and 2-photon immunofluorescence microscopy. The data presented herein constitutes a validation of multicellular human hepatocyte spheroids, cultured in perfusion bioreactor, as a novel valuable tool for long-term in vitro drug induction tests; moreover, the possibility of inducing the human hepatocytes either in the perfusion bioreactor or by taking a sample and subculturing in 24 well plates proves the flexibility of our system for drug testing studies.

Starting year 2008	Estimated date of Completion August-2012	Year of PhD 3 rd	Amount of time spent at MIT 1 year and 2 months
------------------------------	--	---------------------------------------	---

Title of the thesis

Hematopoietic Stem Cell Niches for Cell Expansion and Vascular Differentiation-STEMNICHE

Supervisors

in Portugal: Lino Ferreira (CNC/Biocant)
Claudia Lobato da Silva (IST)
at MIT: Robert LANGER

Research progress and major scientific contributions

Hematopoietic stem cells (HSCs) from umbilical cord blood (UCB) are a rare and heterogeneous population of hematopoietic precursors which are important source of differentiated cells for regenerative medicine. These cells may have potential use for the vascularization of wounds, ischemic heart, diabetes-related vascular diseases, bone grafts and general tissue engineering applications.

One of the main limitations in using UCB-HSCs for regenerative medicine is related to the low number of cells isolated from a typical blood sample. Therefore the development of platforms to efficiently expand these cells is needed. Another limitation is related to the control of their in vivo vascular differentiation. The UCB-HSCs can give rise to several cell lineages and therefore it is important to develop platforms to induce rapidly in situ their vascular differentiation for therapeutic angiogenesis.

During this project, we aim at developing a new set of micro-technologies able to interact with UCB-HSCs in suspension while promoting either their expansion or differentiation into vascular cells. We developed so far part of the micro-technologies able to induce the differentiation of stem cells into vascular cells. Presently we are characterizing their biological effect against human cells.

Swarna Deepa Pandian	India	Bio Engineering	IST
Starting year 2008	Estimated date of Completion August 2012	Year of PhD 3 rd	Amount of time spent at MIT 13 months
Title of the thesis <i>mGluR-dependent LTD and its regulation in the Visual Cortex by Eye Opening and the Onset of Pattern Vision</i>			

Supervisors

in Portugal: Ramiro Almeida (CNCUC), Ana Luísa Carvalho (CNCUC), Joaquim Cabral (IST)

at MIT: Martha Constantine Paton

Research progress and major scientific contributions

The mouse model I am currently using for my thesis study is called Flailer it's a Myosin VA deficient spontaneous mouse mutant.

Flailer has gait and seizure problem using quantitative analyses of Flailer behavior in collaboration with a post-doctoral student and a master's student in my Tomaso Poggio's laboratory I have obtained some extremely exciting data showing that these mice engage in exceptionally long bouts of repetitive grooming behavior, remain isolated from their littermates, and also appear to be asocial. The later is being carefully quantified now requiring a new behavioral venue and many controls for the normal mouse's behavior. The behavior discovered so far is highly reminiscent of autism spectrum disorders well documented in people and in other accepted mouse models. I presented my preliminary studies at the large Society of Neuroscience Annual meeting last November.

The Flailer crosses to C57Bl mice were performed using-C57 GFP mice (Feng et al 2000). These mice strongly express GFP driven by thy-1 promoter in layer V cortical neurons. Consequently it was possible to study the detailed morphology of layer V pyramids in the superficial layers of the visual cortex between Flailer and WT or heterozygous mice. I am also doing live imaging using Two Photon microscope to study the difference between the spine morphology after and before eye opening. This imaging technique involves performing complicated cranial window surgery on 10-day old mice pups. Later through this window real time imaging is done. Last part of my study involves biochemical and molecular biology techniques to analyse levels of protein expressed before and after eye opening in Flailer.

2.2. Leaders for Technical Industries

2.2.1. Overview

The Leaders for Technical Industries (LTI) PhD program within the Engineering Design and Advanced Manufacturing (EDAM) focus area is offered by the Technical University of Lisbon, University of Minho and the University of Porto. This program anchored on multidisciplinary research problems, lying within an Engineering Systems framework. The LTI PhD research program considers that product and process innovation and current complex decision-making must also take into account economics, management and social aspects. This perspective is clarified in the PhD Program Structure that the students must accomplish, where the courses are grouped into clusters, such as Design and Technology (three courses), Engineering Systems (three courses), Engineering Management (four courses), and Leadership.

As an academic program designed to be in close connection with technically advanced industries, the students must complete an internship for the development of integrated research in an industrial environment. The target industrial sectors selected by the program are the automotive, aerospace and medical devices industries. This selection takes into account the current Portuguese industrial profile, and the industrial sectors in which a higher innovative potential is expected over the coming years.

The LTI PhD research program is dedicated to generate new scientific knowledge and new engineering solutions to create and capture value in these industrial sectors. The scope and associated proposals for the program were defined and prepared in fruitful collaboration between faculty and industry leaders. The presentation of the research themes is made by both research supervisors from academia, and by industry research advisors. These presentations take place at special Workshops where the students become familiar with the research themes, the research supervisors and representatives of the industrial sectors. These Workshops, together with a previously prepared research proposal and subsequent discussion at the students' request, enable each student to make a confident choice for their LTI PhD research program. As the Workshop occurs during their first year of study, the students select their subject and prepare, at the end of first year, a thesis proposal which is evaluated by their doctoral committee. For their specific PhD research program, each student must experience an industrial internship, where research is carried out in an industrial environment, and a research activity at MIT (up to six months), as part of the team of their MIT advisor.

Currently, all the PhD research themes are industry oriented and have been defined in closed interaction with the faculty and the industries.

The LTI PhD research programs in which the students are currently working during their third or fourth year of study can be grouped in three main areas: a) Engineering Design and Innovation, b) Engineering Design Management, c) Manufacturing Technologies and Industrial Management.

A wide range of Portuguese and international engineering and technology industries have received EDAM/LTI students. These include: Rolls Royce (UK), General Motors (USA), Continental-Mabor (PT), Volkswagen-AutoEuropa (PT), Hovione (PT), TMG-Automotive (PT), Iber-Oleff (PT), Celoplas (PT), and others described in more detail in another section of this report. The research internship is of vital

importance for the accomplishment of the mission of the EDAM program. It can be performed also in international research laboratories such as ESA in The Netherlands or GKSS in Germany.

The collaboration with MIT is a vital part of the PhD program, where students are encouraged to undertake research activity and several have already accomplished part of their research at MIT.

As a summary of the research that is being developed in the LTI PhD program, the following table groups almost all students into a research grid, under the general theme of Product Development, where the research themes are related with the industrial areas.

Research themes carried out by LTI students.

Research themes	Industrial areas		
	Automotive	Aerospace	Medical Devices
Engineering Design & Innovation	++	—	+
Engineering Design Management	++	+	—
Manufacturing Technologies & Industrial Management	++	+	—

- to + increasing number of students involved

A brief description of the items referred in the table, together with a brief resume of the students work, are presented in the following sections.

Engineering Design and Innovation

Some students are generating scientific knowledge and engineering solutions with strong potential for technological transfer to the health sector. In the Medical Devices subject area, two students in their third year are developing the technology for smart stent-grafts, either in the design, or in the technology of the flexibility of the sensors to be applied on the fibers. Also in this area of Medical Devices a fourth year student is developing a prototype for a novel remote monitoring system to be used by hospitals tracking the recovery of out-patients in their homes. A preliminary prototype has already been installed in a hospital internment floor and is being evaluated for further development. Several international and national publications have been completed.

The theme of Engineering Design and Innovation is being developed in close collaboration with the automotive industry. For example, a fourth year student is designing the application of sensor networks to the automotive interior parts achieving a smart structure with sensing capabilities, and an important Portuguese industry is involved on this research project. A third year student is developing knowledge on the Human Machine Interface on sensitivity functions for the case on non-visual senses (kinesthetic, acoustic and haptic).

Engineering Design Management

Engineering Design Management is a research theme where many students are involved in research, and where several industries are collaborating.

A fourth year student is developing new concepts of Lean in the Design Management area, putting synergies between process standardization and innovation. The application of this study to the improvement of the design process of a complex product such as gas turbines produced by a main European manufacturer is considered a main achievement of the EDAM focus area. Indeed the success of the research performed already has extended the research to related areas in the Engineering Design Management areas of aerospace industry. Also in the aerospace sector, and in direct collaboration with an important European Aerospace research laboratory, a fourth year student is developing decision making tools for the conceptual design of complex engineering systems in a concurrent environment.

In the automotive industry, a fourth year student is investigating the implications on design of materials acquisition costs for a range of products in the particular context of product development. This work will help to identify strategies for decision making that the companies can implement for selecting materials for new products, i.e. “what is the right material for the right application?”.

A third year student is developing strategies for the engineering design of tooling taking into account tooling life cycle cost. Characteristics such as tooling reliability and maintainability, not easily converted into costs, are directly connected with tool design features.

Manufacturing and Industrial Management

This research theme is being developed both with automotive and aeronautics industries. In the automotive industry, two third year students are developing their research on the supply chain network subject. One student studies the supply chain for the automotive industry in an international environment looking across factors (tariffs, rates, tax, legislation, government policies, etc). This information is fundamental but is dynamic and uncertain as the global economy develops. The uncertainties associated with these factors are being studied, and models are being built in order to support strategic-tactical decision-making.

From a more restricted point of view, another third year student studies the implementation of models to improve the flexibility of the single line for automotive assembling as opposed to the just-in-sequence multiple models assembling. This study, which is being pursued in close connection with a major national car manufacturer and an important playmaker in the European automotive industry, will allow business leaders to address volume and model flexibility and cost reduction opportunities to meet the challenges of the low volume niche car market.

In the aeronautic sector a fourth year student is developing research on the implementation of new manufacturing technologies in aircraft structures, when compared to classical joining technologies in aluminum alloys. This research is critical for the aluminum base aeronautics industry to compete with the non-metallic aircraft structures being launched in the market. The research results include the analysis of the impact in the replacement of joining processes in the safety of critical structures, the

investigation of nondestructive techniques to be used, cost and weight analyses, and a final technology assessment based on the design for manufacturing and assembly assumptions.

Coordinators of the Leaders for Technical Industries Doctoral Program

António Torres Marques, FEUP, University of Porto

Chris Magee, Engineering Systems Division, MIT

Joel Clark, Department of Materials Science and Engineering, MIT (LTI director)

Manuel Freitas, IST, Technical University of Lisbon (LTI director)

Olga Carneiro, School of Engineering, University of Minho

2.2.2. Structure

The structure of the doctoral program of the Engineering, Design and Advance Manufacturing area (EDAM), Leaders for Technical Industries (LTI), is described in the next table.

LTI students attend all the courses described in the table below, mostly during their first year but they also have course work during their second and third years. The total of courses makes a total of 70 ECTS but at some of the participating schools (e.g. IST) only 60 ECTS are required.

LTI students are required to spend a minimum of three months and a maximum of twelve months working on-site with EDAM industrial affiliates during the second semester of the 2nd year and the first semester of the third year. At least three months must be spent with a single company; any time beyond this may be spent with additional companies.

Structure of the LTI PhD program

Course	ECTS	Mandatory/Optional	Semester
Product Development	6	Mandatory	1st of the 1st year
Technology Evaluation and Selection	6	Mandatory	1st of the first year
Integrating Technology & Management	6	Mandatory	1st of the 1st year
Companies and Technologies	4	Mandatory	1st of the 1st year
Engineering Systems Research Methods	6	Mandatory	2nd of the 1st year
Engineering and Manufacturing Systems	6	Mandatory	2nd of the first year
Management for Engineering	6	Mandatory	2nd of the first year
Innovation Management	6	Mandatory	2nd of the first year
Operations Management	6	Mandatory	1st of the 2nd year
Advanced Technologies	6	Mandatory	1st of the 2nd year
Production Management	6	Mandatory	2nd of 3rd year
Leadership	6	Mandatory	2nd of 3rd year

During the first half of January students are offered by the Program's committee, a range of project topics for their PhD thesis, which are agreed by faculty and industrial affiliates; and they indicate their preferences by choosing 3 they are most interested in, ranking them from 1 to 3. This choice is communicated to the Program's committee that then facilitates the process and communicates it to the

students by the 31st of January. The student then may choose other co-supervisors to form his/her thesis committee.

Students are required to submit an annual report before the 30th of June each year; that will be revised to establish a thesis proposal. The report should be distributed to the EDAM professor in charge of the LTI class and the thesis committee. The thesis committee members should individually provide brief written comments (less than one page) on the report to the student, thesis supervisor, and EDAM professor within one month of receiving the progress report (i.e., by July 30th). Reports with negative remarks from the committee should be analyzed by the supervisor and the EDAM professor in order to withstand eventual corrective measures. Students should be informed of the results of this evaluation before the 1st of September.

The first thesis committee meeting should be scheduled shortly after students receive this feedback. This first meeting should be viewed as a defense of the thesis proposal. The thesis committee should meet with the student at least twice per year.

Students are awarded an LTI PhD when they meet the following requirements:

- Completion of all ten courses with a passing grade or higher (ten out of twenty)
- Completion of a minimum of three months and a maximum of twelve months of industrial internship(s) with at least three months at one firm
- Successful defense of the thesis with a pass recommendation by the majority of the committee
- Submission of a signed thesis document

2.2.3. Student highlights

Alexandre Silva, enrolled at UM, follows a research activity in Engineering Design and Innovation applied to automotive industry under the theme “Automotive Smart Flooring based on photonics”, and he has published three papers in international Journals and several presentations in international conferences. Alexandre just won the 8th edition of the PVC Iberian Forum Award (January 2011), and has commented on his experience at MIT:

‘The MIT experience was in overall very positive will full accomplishment of the proposed tasks. While in Portugal I mainly focused my work in technical aspects, at MIT my goal was to work on cost modeling regarding the solution that was been studied in Portugal. I had the opportunity to attend classes and work closely with the teams that were expertise in this field of cost modeling.’

Alexandre Silva, UMinho

Inês Ribeiro, enrolled at IST, with a research activity in Engineering Design Management under the research theme ‘From Tooling Design to Tools Life Cycle Design: Shifting the Paradigm’ she has co-authored two papers in international journals, two book chapters and nine presentations in international conferences. Inês Ribeiro has spent time doing research at MIT and she offer the following about her stay:

‘ To be short, my stay was in personal terms a culturally rich and unique experience. Academically, I was fully integrated in a research group with the pressure of presenting all weeks the progress of my work and I further developed the knowledge I needed for my thesis model. Finally, I also had the opportunity to spend some weeks in GM (Detroit) in a short internship, a quite hard but intensive experience. In the end, I think all MIT-Portugal students should take advantage of this opportunity that the program gives us.’

Inês Ribeiro, IST

Sérgio Tavares, enrolled at FEUP, has a research activity in the area of Manufacturing Technologies and Industrial Management under the theme “Design and Advanced Manufacturing of Aircraft Structures using Friction Stir Welding”. He has published three papers in international journals and several presentations in international conferences. Sérgio did some of his research work at MIT and he made these comment about his experience:

‘The time spent at MIT allowed to embrace additional research topics which were not possible if the research was confined to one place. My experience mainly involved the materials joining lab and companies with last advanced technologies for non-destructive testing. The MIT excellence, with its density of resources and knowledge, gave me a different vision and perspective, enhancing the research results and personal experience.’

Sérgio Tavares, FEUP

2.2.4. New courses and faculty involved

For the EDAM educational programs (TME and LTI) 12 new courses have been specially designed. These courses are taught by 29 faculty members from the 3 participating Portuguese schools in this area and by 10 faculty members from MIT. MIT faculty ensures 28% of the teaching (academic year 2010/11).

2.2.5. Use of open-source community-based tools for learning

The EDAM area uses the Moodle e-learning platform where the syllabus, pre-readings, PowerPoint presentations, bibliography, and assignments for each of the courses are made available to students. The faculty uses this platform to interact with students and the students interact with each other and faculty through the same system.

2.2.6. Benchmarking

EDAM’s degree programs (LTI and TME) are geared towards training students to become technical managers in engineering design and advanced manufacturing industries. The LTI program is specifically focused on developing competencies in students that can be used to drive research and development capabilities within a technical firm. There are several unique elements of the programs, including:

- Diversified mix of courses in design and technology (including product development and design), engineering systems, and systems management (including innovation management and leadership)
- Thesis research with an industrial partner

- An internship with an industrial partner (LTI only).

Numerous degree programs exist worldwide in the areas of engineering design, advanced manufacturing, and engineering management, but few have the same basic elements as the two EDAM degree programs. Thus, this benchmarking study includes an analysis of other programs across the world with some elements that are similar to TME and LTI, which are presented in the following table. Programs that focus purely on design, manufacturing, or engineering management were not included in this analysis because they do not have the desired breadth that is sought in EDAM's programs. Master's and doctoral programs are combined in this evaluation because of the significant amount of overlap between the TME and LTI programs.

Summary of results

Key elements of ten degree programs in Europe and the US similar to EDAM's programs are listed in the table below, which include two main doctoral programs that were found to be closer to LTI.

There are several features that these programs have in common:

- Multidisciplinary course content including design and management topics
- Extensive interaction with industrial partners
- A thesis or final project that is tied to the interaction with industrial partners

The EDAM programs have several unique features:

Engineering systems and leadership courses in the curriculum

- Thesis research and internship with an industrial partner in a doctoral program
- American and European faculty from four universities collaborating to coordinate the program and teach the courses
- Block schedule that enables students to work at a company while taking courses.

There are also a few areas where some of the programs have advantages over the EDAM programs:

More partnerships (financial and academic) with large companies

- More extensive selection of electives across numerous subject areas

This is because the schedule format that entails classes being taught during intensive two-week periods at three different universities does not facilitate a wide range of options. While this format enables students to work at a company while taking courses, it means that students are not able to take courses available outside of the EDAM program at the host universities. Thus, as long as EDAM maintains the current class delivery format, the courses available to students will be limited to those directly taught as part of the EDAM degree programs (which is currently twelve courses).

Key characteristics of doctoral and master's programs analyzed in benchmark study

University Name; School; & Location	Degree Name	Degree Type	Curriculum	Thesis Requirement	Internship Requirement
Brunel University; Graduate School; West London, UK	New Route PhD – Design and Systems Engineering ¹	PhD	<ul style="list-style-type: none"> • Engineering research methods • Management and production planning • Communication skills • Global context • Discipline-specific modules: <ul style="list-style-type: none"> ○ Design research creativity and innovation ○ Design management and marketing ○ Branding strategy ○ Design of perception enhancement systems 	Yes	No
Dartmouth University; School of Engineering; Hanover, NH, USA	PhD Innovation Program ²	PhD	10 courses in typical engineering areas, supplemented with entrepreneurial studies including: <ul style="list-style-type: none"> • new venture creation • finance • accounting • patent law • marketing 	Yes	3- to 6-month internship in a startup or other entrepreneurial enterprise
Advanced Design and Manufacturing Institute ³ ; Toronto, ON, Canada	Master of Engineering in Design and Manufacturing ⁴	MEDM	~10 courses delivered in a format similar to EDAM programs. Minimum five courses from a Technology & Process Stream and a minimum of two courses from a Business and Management stream.	An approved industry project may replace two courses	Potential industry project.

¹ <http://www.brunel.ac.uk/courses/pg/research/newroutephd/desys>

² <http://engineering.dartmouth.edu/graduate/innovation/>

³ Partnership of the University of Waterloo, University of Toronto, McMaster University, Queen's University, and University of Western Ontario

⁴ <http://www.admicanada.com/>

Dartmouth University; School of Engineering; Hanover, NH, USA	Master of Engineering Management	MEM	~14 courses in mathematics, design, and engineering management	Complete project as part of internship	3 months
Ecole Polytechnique Federale de Lausanne; College of Management of Technology; Lausanne, Switzerland	Master in Management, Technology and Entrepreneurship ⁵	MMTE	Students take core courses in probability, data analysis, and decision analysis and have the option of two “orientations”: “Strategy, Innovation & Entrepreneurship” or “Operations Management & Systems Modeling”; electives are also available.	“Master Project” conducted in industry	6 months
Massachusetts Institute of Technology; Engineering Systems Division; Cambridge, MA, USA	Leaders for Global Operations ⁶	SM & MBA	~20 courses, including MBA core curriculum: foundations, integration, leadership	Yes	6.5 months
Massachusetts Institute of Technology; Engineering Systems Division; Cambridge, MA, USA	System Design and Management ⁷	Master’s in engineering & management	15 courses: core courses in systems architecture, engineering, and management; foundations courses; and elective courses.	Yes	No
Northwestern University; Segal Design Institute; Evanston, IL, USA	Master of Science in Engineering Design and Innovation ⁸	MS-EDI	~12 courses primarily focused on design; students specialize in a “design theme”, which include business factors or entrepreneurship.	Thesis project	Yes

⁵ <http://smte.epfl.ch/site/smte/master-mte>

⁶ <http://lgo.mit.edu/>

⁷ <http://sdm.mit.edu/>

⁸ <http://www.segal.northwestern.edu/graduate/>

Northwestern University; Kellogg School of Management & McCormick School of Engineering; Evanston, IL, USA	MMM Program ⁹	MBA and MEM (Master of Engineering Management)	~30 courses (quarters schedule) in business, engineering management, and electives in design or operations.	Integration Project with a team of students	No
University of Cambridge; Institute for Manufacturing; Cambridge, UK	MPhil in Industrial Systems, Manufacture and Management (ISMM) ¹⁰	MPhil	ISMM is 39 weeks. The content is split as follows: <ul style="list-style-type: none"> • Eight weeks of project work (four projects) • Thirteen weeks of taught modules: manufacturing systems, manufacturing processes, product design, technology management & entrepreneurship, leadership • A two-week overseas study tour, either in mainland Europe or further afield. • A thirteen week dissertation project working with researchers at the Institute 	Dissertation project 13 weeks	No, but lots of interaction with companies

⁹ <http://www.mmm.northwestern.edu/>

¹⁰ <http://www.ifm.eng.cam.ac.uk/ismm/default.html>

2.2.7. Educational initiatives

All-faculty events

Since the beginning of its second year, the EDAM focus area carries out an all-faculty event that aims to discuss the program, but also to train faculty on the topics of engineering systems.

The first all-faculty meeting took place in Lisbon on September 2008. The meeting fostered the interaction between EDAM faculty, EDAM researchers, and MIT. The short course had the participation of more than 40 people, including EDAM faculty and EDAM researchers from the 3 Portuguese cooperating universities and MIT. This was the ideal place to discuss the Engineering systems components addressing both the educational programs and on going research projects.

The second meeting was held in Porto on September 2009. The first day was devoted to a teaching workshop, with the objective of reviewing recent and/or important topics in teaching and learning paradigms and methodologies, and of discussing how to incorporate them into the EDAM education programs. The second day was devoted to research, in order to review the content of EDAM research projects and discuss ways in which key characteristics of the projects could be strengthened.

The third meeting was held in Guimarães in September 2010. For the first time the meeting included the participation of the EDAM students. The first day included “Research Outcomes from Three Years of the LTI Program”, with the goal to reviewing the outcomes from three years of student research activities in the LTI program. The second included faculty and Industrial Affiliates only, and consisted of an in-depth evaluation of the research presented on the previous day and a discussion on mechanisms to improve the incorporation of topics of interest to Industrial Affiliate into EDAM courses.

Building team events

A team-building exercise for new LTI and TME students was performed in the beginning of the first week of courses in the academic years 2008/09 and 2009/10 as a way of facilitating camaraderie among the students prior to the start of classes.

Regular visits to companies

Visits to industry are performed by LTI and TME students during their first year. Some of the visited companies include: Autoeuropa, Continental Mabor, TMG, Sunviauto, CEIIA, and Salsa.

Networking activities during class periods

Networking and brainstorming activities are often organized during the lecturing periods to stimulate the students. Examples are:

- EDAM Session at CEIIA – Thursday, 17.April.2008 (12:15 – 15:00) with the presence of Secretary of State Prof. Manuel Heitor
- EDAM Workshop/Group dynamics Event: 18:00 – 20:00, 17th June 2009, Praça da Oliveira, Guimarães. Informal discussion about leadership with participation of Partha Ghosh
- EDAM Workshop: Rethinking Product Design and Manufacturing for a Changing World 17:00-22:00, 10th March 2010, FEUP

2.2.8. PhD theses

This section shows the profiles of each student who has spent some period of time at MIT.

The home institution of each student is indicated on the first line as:

FEUP – Faculty of Engineering – University of Porto

IST – Instituto Superior Técnico – Technical University of Lisbon

UMinho – School of Engineering – University of Minho

Alexandra Sepúlveda	Portugal	LTI	UMinho
Starting year 2008	Estimated date of Completion 10/2012	Year of PhD 3 rd	Amount of time spent at MIT 6 Months

Title of the thesis

Technologies for flexible sensors in the design of a smart stent-graft

Supervisors

in Portugal: António pontes (UMinho), Júlio Viana (UMinho)

at MIT: Brian Wardle

Main Publication

A.T. Sepúlveda, A. Moreira, F. Fachin, B.L. Wardle, J.M. Silva, A.J. Pontes, J.C. Viana, L.A. Rocha: *Inductive-Coupling System for Abdominal Aortic Aneurysms Monitoring Based on Pressure Sensing* – 21st Micromechanics and Micro systems Europe Workshop, MME 2010, September 26-29, Enschede, The Netherlands, 2010.

A.T. Sepúlveda, Isa C.T. Santos, F. Fachin, R. Guzmán de Villoria, B.L. Wardle, A.J. Pontes, J.C. Viana, L.A. Rocha: *Design of a Pressure Sensor for Monitoring of Post-Endovascular Aneurysm Repair* – International Conference on Biomedical Electronics and Devices, Biodevices 2011, 26 – 29 January, Rome, Italy, 2011.

A.T. Sepúlveda; A.J. Pontes; J.C. Viana; L.A. Rocha: *Aligned Carbon Nanotubes Composites for Flexible Pressure Sensors* – VI International Materials Symposium MATERIAIS 2011 (XV meeting of SPM – Sociedade Portuguesa de Materiais), 18-20 April, Guimarães, Portugal, 2011. Accepted.

Research progress and major scientific contributions

The aim of this work is to develop a new pressure sensor technology to include in a stent-graft, for the pressure measurement within an aneurysm sac for post-EVAR surveillance. Given the characteristics of the application, the capacitive sensor must be foldable, extremely flexible and characterized by a very small profile. In addition, the technology should be simple and biocompatible. Silicon based microtechnologies are widely used in implantable medical devices, but due to the application specifications, a new fabrication process is being developed.

The proposed fabrication process uses aligned carbon nanotubes (CNTs) to build the conductive elements. The CNTs are embedded in a flexible substrate of polydimethylsiloxane (PDMS), a transparent, nontoxic and biocompatible silicone elastomer. Acrylic moulds were produced by CNC milling for posterior fabrication of the PDMS membranes and chemical vapour deposition (CVD) was used to grow forests or “carpets” of vertically-aligned CNTs. This method has the advantage of allowing growth of high purity, high yield and vertically aligned morphology. Next, the CNTs were embedded into the polymer matrix (PDMS) and the substrate was placed against the moulds, followed by the PDMS introduction in the cavities through a hole. The last step was the cure of the elastomer.

For mechanical characterization, PDMS-CNTs specimens, moulded into rectangular shapes with dimensions of 32x14x0.4 mm³ (LxWxH), were subject to tensile tests to obtain the elastic modulus. Through the representative stress-strain curve, the tested membranes present an elastic modulus of about 1.23 MPa (at the initial stage) and a large piezoresistive effect. For electrical characterization, the conductivity was measured using a movable four-point probe in contact with a series of PDMS-CNTs composites films. The measurements indicate an electrical conductivity of 0.35 S.m⁻¹ with a standard deviation of 0.37 S.m⁻¹.

Alexandre Silva	Portugal	LTI	UMinho
	Estimated date of	Year of PhD	Amount of time spent at MIT

Starting date 2007 **completion** July/2011 4th 4 months

Title of the thesis
Automotive Smart Flooring based on photonics

Supervisors

in Portugal: José Higinio Correia (UMinho)
Paulo Mateus Mendes (UMinho)
at MIT: Joel Clark
Richard Roth

Main Publication

A. Ferreira da Silva, A. Goncalves, L. de Almeida Ferreira, F. Araujo, P. Mendes, and J. Correia, "A Smart Skin PVC Foil Based on FBG Sensors for Monitoring Strain and Temperature," IEEE Transactions on Industrial Electronics, 2010.

A.F. Silva, A.F. Goncalves, L. A. de Almeida Ferreira, F.M. Araujo, P.M. Mendes, and J.H. Correia, "PVC Smart Sensing Foil for Advanced Strain Measurements," IEEE Sensors Journal, vol. 10, 2010, pp. 1149-1155.

A.F. Silva, A.F. Goncalves, P.M. Mendes, and J.H. Correia, "PVC formulation study for the manufacturing of a skin smart structure based in optical fiber elements," Polymers for Advanced Technologies [in press]

Research progress and major scientific contributions

The initial goal was to develop a novel inner car smart flooring concept, able to sense chassis deformation when car accident or collision occurs. However, it was soon detected that smart flooring could have a broader application field. Optical sensors have greatly evolved, offering nowadays a high performance alternative in many different areas, for measuring strain, temperature and can be already found in the automotive, aeronautics or biomedical field. However, the application of these monitoring systems is not a straightforward task, especially, at the sensor application step.

A smart structure with sensing capabilities would overcome the existing installation issues of sensor networks. Based on the significant system size and the market requirements, an industrial manufacturing process was considered. An integrated solution with Fiber Bragg Grating sensors embedded in PVC laminates manufactured by industrial spread-coating process was explored. The resultant structure is a temperature and strain sensitive foil characterized in terms of surface structure, optical response and overall performance. The industrialization problematic was evaluated, not only by developing a machine for an automated fiber insertion in the PVC laminate, but also by evaluating the customization of the smart structure, regarding fiber layout, sensor disposition and finish styles. Furthermore, a cost-model has been developed for the smart foil production in order to evaluate the cost drivers and the competitive advantage against the traditional method for sensor installation.

The research work has been developed in a successful collaboration with *TMG Automotive* (included an industrial internship) and *Fibersensing* companies. The student had also the opportunity to stay in MIT during 4 months, developing the cost-model.

The developed work resulted in the publication of 5 articles in international journals with peer-review and 6 oral communications in international conferences.

Carla Pepe	Portugal	LTI	IST
Starting year 2007	Estimated date of completion 2011	Year in PhD 4 th	Amount of time spent at MIT 1 week
Title of the thesis <i>A Framework to Improve Complex Design Processes</i>			

Supervisors

in Portugal: Elsa Henriques, IST
at MIT: Daniel Whitney, MIT

Main Publication

Pepe, C., E. Henriques, et al. (2008). Lean Principles in Product Development. RPD 2008 – Rapid Product Development, Oliveira de Azeméis, Portugal.

Pepe, C., D. Whitney, et al. (2010). Engineering Process Improvement Using Value Stream Mapping and Design Structure Matrix Tools. First International Conference on Modelling and Management of Engineering Processes. Cambridge, UK: 101-112.

Pepe, C., D. Whitney, et al. (2011). Engineering Process Improvement Framework Development. International Conference on Engineering Design, ICED11. Technical University of Denmark – under selection process

Research progress and major scientific contributions

The complexity of designing products such as gas turbine components leads to enormous difficulties in understanding where the main design process inefficiencies are. It is extremely difficult to decide which improvements will have the most significant impact for a company or for a specific project. Another common issue found in the Aerospace industry is a consequence of basing a new gas turbine design on a previous concept and is that most of the time people don't question the overall design process.

These issues, alongside a companies' matrix organization, create difficulties in managing and improving the design processes. In order to overcome the mentioned problems, a framework has been developed and used in two case studies at Rolls-Royce plc.

This framework developed in this thesis aims to assess and improve in a systematic way, complex product development processes at component or system level. The framework involves the use of Value Stream Mapping (VSM) analysis to identify waste sources in the design process, the use of Design Structure Matrix (DSM) to manage design iterations and interfaces complexity and Process Simulation to deal with the stochastic behaviour, and finally estimate and assess the benefit of potential developments.

Cláudia Duarte	Portugal	LTI	UMinho
Starting year 2008	Estimated date of Completion 12/2011	Year of PhD 3 rd	Amount of time spent at MIT 3 months
Title of the thesis <i>Single line for assembly just-in-sequence multiple models</i>			
Supervisors			

in Portugal: José Valério Carvalho (Uminho) and Ana Paula Pova (IST)
at MIT: Stanley Gershwin

Research progress and major scientific contributions

The European automotive industry faces new challenges related to the growing of competitiveness. As an important playmaker in the European automotive industry and as the second national exporter, AutoEuropa is the major partner in this project. They need to address volume and models flexibility and cost reduction to meet the new market challenges. Because of this, recently, AutoEuropa implemented the concept of a single line, which is able to assemble just-in-sequence multiple models in a single line assembly. This line produces 4 models: EOS, Scirocco and a model that they call MPV (composed by 2 models one of Seat and the other from Volkswagen). This is a challenge and this project aims to obtain sequencing policies to ensure the delivery of the vehicles just in sequence without degrading the efficiency of the system. In this project we intend to formulate:

- the decision problem that consists in deciding whether it is possible to find a sequence that satisfies all capacity constraints;
- the optimization problem that involves finding a minimum cost sequence, where the cost function evaluates constraint violations.

To achieve these goals we made a study of the existent modeling and optimization methods for car sequencing used on different automotive industries. We made also a study and characterization of Autoeuropa manufacturing system. Based on this study we are developing now a model for the Car Sequencing Problem using Mixed Integer Programming and the IBM ILOG software. At this moment we are testing the model with Autoeuropa and preparing an article for the conference IO 2011.

The Mixed Integer Programming Model for the Car Sequencing Problem that we are developing has something new that was not used by any researcher until now and because of this cannot be revealed. To reduce the computation times, that are usually high for big problems, in this kind of models, we are trying to find new cuts for the model. If we achieve this goal it will be a good contribution also.

Helena Fernández López	Spain	LTI	UMinho
Starting year	Estimated date	Year of PhD	Amount of time

2007 **of Completion** 4th **spent at MIT**
 Sept/2010 1 month

Title of the thesis

Wireless communication sensor networks for remote health monitoring

Supervisors

in Portugal: José Higinio Correia (UMinho), Ricardo Simões (UMinho and Cávado and Ave Polytechnic Institute), José Afonso (UMinho)
 at MIT: Chris Magee

References of the three best publications on PhD research

H. F. López, J. H. Correia, R. Simões, J. A. Afonso, “Experimental Evaluation of IEEE 802.15.4/ZigBee for Multi-Patient ECG Monitoring”, 4th International Conference on Pervasive Computing Technologies for Healthcare (eHealth 2010), Casablanca, Morocco, in press.

H. F. López, J. A. Afonso, J. H. Correia, R. Simões, “HM4All: A Vital Signs Monitoring System based in Spatially Distributed ZigBee Networks”, 4th International Conference on Pervasive Computing Technologies for Healthcare (PervasiveHealth 2010), Munich, Germany, March 2010.

H. F. López, P. Macedo, J. A. Afonso, J. H. Correia, R. Simões, “Evaluation of the Impact of the Topology and Hidden Nodes in the Performance of a ZigBee Network”, in Lecture Notes of the Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering, Imrich Chlamtac (Ed.), First International Conference on Sensor Systems and Software (S-Cube 2009), Pisa, Italy, September 2009.

Research progress and major scientific contributions

This work combines medical sensors and wireless sensor network (WSN) technologies, namely the IEEE 802.15.4 and the ZigBee protocols, to design a cost-effective, easily-deployed system capable of gathering vital signals from in-hospital patients and recovering patients at home and present them into a nurses’ station.

The major contributions are:

- The prototyping of a novel remote monitoring system to be used in hospital environments where, presently, patients are not continuously monitored and by recovering out-patients at home
- The performance evaluation and commissioning of the of the prototype system on an internment floor of a private hospital in Portugal
- The development of a ZigBee to Wi-Fi gateway which is responsible for interfacing the ZigBee personal area network (PAN) coordinator with the Internet
- The development of wearable ECG/heart rate and axillary temperature prototype sensors, including the hardware and the firmware.

Currently, the established goals for my work are almost achieved. A prototype system is already installed in a hospital internment floor and is being evaluated. Five articles were presented in international peer-reviewed conferences and one more will be submitted by Feb 11th. The thesis is being written and, in two months, an article will be submitted for an international journal.

Inês Ribeiro	Portugal	LTI	IST
Starting year	Estimated date of	Year of PhD	Amount of time

2008

Completion
2011/2012

3rd

spent at MIT
3 months

Title of the thesis

From Tooling Design to Tools Life Cycle Design: Shifting the Paradigm

Supervisors

in Portugal: Paulo Peças (IST), Elsa Henriques (IST), António Pontes (UMinho)
at MIT: Rich Roth

Main Publication

Peças P, **Ribeiro I.**, Folgado R., Henriques E. A Life Cycle Engineering Model for Technology Selection: a Case Study on Plastic Injection Moulds for Low Production Volumes. *Journal of Cleaner Production*, Vol. 17 (9), pp. 846-856, 2009.

Peças, P., Henriques, E., **Ribeiro, I.** Integrated Approach to Product and Process Design Based on Life Cycle Engineering. *Handbook of Research on Trends in Product Design: Technological and Organizational Perspectives*, pp. 394-417. Business Science Reference, Hershey, NY, 2010.

Ribeiro I., Peças P., Henriques E. Life Cycle Engineering applied to design decisions, a case study. *Proceedings of the 16th International CIRP Conference on Life Cycle Engineering 2009*. Cairo, Egypt.

Research progress and major scientific contributions

The design and production of tools is a time consuming, technically difficult and expensive activity. Moreover, tool design choices highly affect the manufacturing process in which they are used. Sometimes the least expensive tool does not lead to the least expensive part option if other processes in which it's used are considered. It is then necessary to shift the paradigm from the cost of the tool as the decision factor to the tool life cycle cost and even other aspects not included in conventional costing. In this context, this research presents a new methodology to approach decision making in the tooling industry. In order to develop a life cycle approach based on LCC methodology, the technological cost models comprising the life cycle stages of a dedicated tool are combined. By this, the engineering knowledge regarding physical, statistical or empirical relations is applied to model the processes and through the process the resources requirements are estimated. Regarding characteristics as reliability and maintainability, these are not easily converted into costs when it comes to a dedicated tool, as it is also in most cases impossible to obtain statistical valid samples, due to the fact that each tool is a complex and unique product. However, tool designers and users have an experience-based capability to assess these aspects, although qualitatively. By using these subjective judgments, this research intends to capture their non-structured knowledge into the cost models. Furthermore, the design decisions are also investigated having into account not only the cost, but the different stakeholders' preferences. In a real industrial context decisions are not based on tangible costs. Some aspects such as reliability, maintainability and production time have more importance than the reflected in the conventional costs. The last phase of the research aims to capture these preferences by integrating them in the results achieved by the cost models and hence computing a comprehensive life cycle cost.

Finally, this approach was applied to industrial case studies and through internships in four different companies (Celoplás – Grimancelos, Famolde – Marinha Grande, Fapil – Malveira, GM – Detroit) was possible to apply the methodology. Furthermore, the stay in MIT developed my knowledge in cost models. From these experiences several scientific publications in international journals, scientific books and international conferences were possible.

Isa Santos	Portugal	LTI	FEUP
Starting year 2008	Estimated date of Completion 2012	Year of PhD 3	Amount of time spent at MIT 4 months
Title of the thesis <i>Concept selection in the development of medical devices: the case of the smart stent-graft</i>			

Supervisors

in Portugal: João Manuel R.S. Tavares (FEUP)
Luís Alexandre Rocha (UMinho)
in the USA: Jeremy Gregory (MIT)
Scott Gazele (Harvard)

Main Publication

No publication so far in a peer-reviewed journal. However, several papers have been published in peer-reviewed conference proceedings, and a book chapter is in press.

Research progress and major scientific contributions

To meet customers' requirements, designers narrow down an array of ideas to a single one. This process is named concept selection and it is crucial to efficiently develop novel products because, from this point onward, the designer team is committed to a concept whose change implies delays and additional costs. At this stage, the lack of objective data makes decisions insubstantial. However, it is possible to reduce uncertainty assessing the products' expected costs and benefits to select concepts. In the medical device sector, before products are brought to market, they are subject to the scrutiny of different agencies around the world to assess their clinical and cost-effectiveness. In this project, those criteria have been analyzed and adapted to define a new concept selection technique. The method under development is going to be applied to the development of a smart stent-graft, but other possible applications are possible.

So far, the product development process was described along with the distinctive features of medical devices. Additionally, a new concept selection technique is being delineated. To validate the new methodology, a case study was defined: the development of a smart stent-graft. Regarding this topic, the customers were recognized and their needs were gathered through questionnaires to both patients and doctors.

Ivo Ferreira	Portugal	LTI	IST
Starting date 2007	Estimated date of completion Oct-Dec/2011	Year of PhD 4 th	Amount of time spent at MIT 4 months

Title of the thesis

Towards a better conceptual design of complex engineering systems in a concurrent environment

Supervisors

in Portugal: Paulo Gil – IST (Main advisor) Pedro Oliveira – UMinho (Co-advisor)
at MIT: Olivier de Weck (Co-advisor)

Main Publication

Gil, P. J. S., **Ferreira, I. M. L.** (2011 - under review). A Conceptual Concurrent Design Methodology for Complex Engineering Systems. *Journal of Mechanical Design*

Ferreira, I. M. L., Gil, P. J. S. (2011 - under review). Analyzing the performance of multilayer perceptron neural networks to support decisions during the conceptual design phase. *Expert Systems with Applications*

Gil, P. J. S., Rosa, P. M. B., & **Ferreira, I. M. L.** (2010). Modern approaches in the design of complex aerospace systems. *Journal of Aerospace Engineering, Sciences and Applications*, 2(1), 15–26.

Research progress and major scientific contributions

This research focuses on the conceptual design methodologies for complex engineering systems. By analyzing the prominent concurrent philosophy environment and its shortcomings and studying the capabilities of currently existing technologies, an integrated design process is proposed.

The typical conceptual design process is analyzed with respect to four key areas and their impact on the design performance: system representation, common algebras that can be used to represent the system behavior, possible optimization methods and knowledge management incorporation. The aim is to increase the quality of design solutions at the conceptual stage and enhance the perception of the system by allowing simultaneous real-time perspectives of the “forest” (global system level) and the “trees” (subsystems level).

In order to address the main issues detected, focusing at the global system level, an integrated design process is proposed including general system description, requirements mapping, interaction, and optimization stages. The interaction stage is implemented in a software tool providing visualization and interactive models to enable decision support, dependencies tracking and design documentation by using an adapted dynamic Design Structure Matrix (DSM) of the system throughout the design process.

Focusing at the subsystem level, an intuitive standalone decision support tool based on neural networks to predict design suggestions is also detailed. The design performance gain is measured through a set of case studies from different fields (aerospace, automotive, etc.) and with different levels of complexity.

The thesis contributes to the literature on conceptual design, concurrent engineering, design structure matrix, and neural networks for design purposes. It proposes a rigorous means of incorporating a global view on the system analytical performance with tacit knowledge brought by the designers. Finally, shows the applicability of prediction tools and the impact of enhanced representation models during the conceptual design phase.

Lia Oliveira	Portugal	LTI	FEUP
Starting year 2008	Estimated date of completion July/2012	Year of PhD 3 rd	Amount of time spent at MIT 5 months

Title of the thesis

Increasing flexibility and collaboration in the automotive supply chain network

Supervisors

In Portugal: Jorge Pinho de Sousa (FEUP); João Claro (FEUP)
At MIT: Richard De Neufville

Main Publication

A paper is currently being written, presenting the main results already achieved in our research.

Research progress and major scientific contributions

Nowadays, industrial organizations set their efforts more and more on the control and reduction of costs, not only as a way to fight the growing market competition but also to overcome the problems posed by the current global economic and financial crisis. The automobile has been one of the most affected sectors, facing a decrease in sales since the last quarter of 2008. The economy slowdown has contributed to a profound restructuring of this sector. To pursue competitiveness, automotive companies need to improve the way they operate with the market and with their own networks, to invest in innovation, to carefully look at activities planning and at supply chain opportunities. It is fundamental to systematically evaluate and (re-)design the production and distribution systems as well as to define strategies to provide the desired customer service at the lowest possible cost. In this context, more research is being dedicated to supply chain design and management, aiming at improving components of systems already in place or at building new components of those systems.

A global supply chain involves several countries and consequently it becomes fundamental to look across international factors, such as tariffs, exchange rates, duties, income tax legislation, national production resources, transfer prices, government policies, trade barriers and competition. Some of these factors increase the level of uncertainty in a supply chain but are not the exclusive factors in that direction.

We are developing models for the automotive industry dealing with different types of uncertainty, and in particular we want to develop a stochastic model for the global automotive supply chain network to support strategic-tactical decision-making. Moreover we also want to cover a set of different features of real, practical environments, namely: multi-periods planning horizons (understanding and managing the impact of changes), multi-criteria assessment of policies (including costs and customer service level), international parameters (as legislation) and the major concerns of companies. Here our perspective is that of a first or second tier supplier. In this context, some strategic decisions can be episodic. For example, a customer is opening a new plant and we need to understand how supplying this new customer site can be better integrated, in time, in its supply chain network. The models we are developing should help in decision-making on the operations strategy planning, and also in understanding how the supply chain network should evolve in a long-term time horizon, in order to optimize the profitability of operations. For such purpose, these models will require the definition of scenarios for future evolution of supply, demand, transportation and other critical elements of the SC network. They will also imply the definition of relevant new investment alternatives; simulating and optimizing investment decisions in time; and sensitivity analysis to understand under which conditions different investment alternatives may become more attractive. All these different issues are now being researched, although not at the same stage. Critical inputs to the work are being provided by the case study we have being defining with the valuable collaboration of the SIMOLDES Group, our industrial partner in the project.

Marco Leite	Portugal	LTI	IST
Starting date 2007	Expected date of completion 2011	Year of PhD 4 th	Amount of time spent at MIT 7 months
Title of the thesis <i>Materials selection considering technical performance, process cost and life cycle evaluation</i>			
Supervisor in Portugal: Arlindo Silva (IST), Elsa Henriques (IST)			

References of the three best publications on PhD research

M. Leite, A. Silva, E. Henriques, R. Roth, The implications of decisions on the material mix problem: the case of small stampings in the automotive industry, submitted to ICED 2011, 15 to 18 August 2011, Copenhagen, Denmark.

M. Leite, A. Silva, E. Henriques, Materials selection in product design and development. RPD 2008, 29 to 30 October, Oliveira de Azeméis, Portugal.

M. Leite, A. Silva, E. Henriques, Material and technology issues in the early phases of product design: an example from the automotive industry. IRF'2009, 20 to 24 July, 2009, Oporto.

Research progress and major scientific contributions

A successful product development increases pressure in the manufacturing companies to outperform competitors. These companies must be capable of developing products with more quality, lower product cost, shorter development time and shorter development cost. One of the major activities inside the development process is the one related to materials and manufacturing process selection. Materials selection is complex in nature and influence and is influenced by the product development process. Materials are responsible for products' function, structure and in some cases interaction with the customer/user.

Most materials and process selection methods seldom deal with this complexity. Although trying to respond to the question: "what is the right material for the right application?" with the objective of matching properties to required specifications, they are often simplifying issues related with a holistic view of the product and particular context of the manufacturing organization. Consequently, matching properties for a single product instead of a range of products and on an ideal organization instead of the particular context of the manufacturing firm can yield a preferred material that is unlikely to be the overall optimum choice.

This thesis investigates the implications on design of materials acquisition costs for a range of products and with a particular context in product development materials selection decisions and seeks to identify strategies for decision-making that the companies can implement for selecting materials for new products. To that purpose, a framework for incorporating materials acquisition costs, for a range of parts, in an exogenous context is proposed and demonstrated using two case studies, the first with single product and single materials selection in an automotive manufacturer context and the second with a range of parts and material mix decisions in a Tier 1 manufacturer context. In the first case, materials selection is defined by a trade-off between engineering properties, economical cost and environmental impact. In the second case, the problem is more complex and requires combinatorial optimization techniques to select the best material mix for a large number of parts with multiple materials available and dependent in the company procurement strength.

Ricardo Torcato	Portugal	LTI	FEUP
Starting year 2008	Estimated date of Completion July 2012	Year of PhD 3 rd	Amount of time spent at MIT 3 months
Title of the thesis <i>An expert decision support system for concurrent development of RIM parts</i>			

Supervisors

in Portugal: Ricardo Santos (FEUP), Madalena Dias (FEUP)
at MIT: Richard Roth

Research progress and major scientific contributions

In order to identify and organize the knowledge required for the development process of Reaction Injection Moulding (RIM) parts and processes, two US RIM companies were visited and their experts provided valuable information that enabled us to redefine the scope of study and the objectives of this research. During the visits we confirmed the general lack of explicit consideration of the downstream processes in the concept development stage.

Considering:

1. The literature review on product development and tools to incorporate expert knowledge in the part and process design, and the cost estimation techniques
2. The need for a validated design that will provide insight into metrics such as development lead time and manufacturing costs to deal with the decision makings required in early stage design in order to reduce the subsequent redesigns and reworks.

It is our belief that the concurrent concept development is the appropriate approach.

Nevertheless, the inherent complexity and intensive knowledge requirements of this concurrent development problem, as well as the scarcity of human experts in the field, raises the need to develop an Expert System (ES) for the concurrent design of RIM parts (that starts with inputs of customer requirements on product features, both functional and aesthetic, and ends with outputs that determine part material, mould design features, mould-making processes, moulding processes, and cost estimations of mould fabrication and moulding operation).

An ES architecture and framework, which emphasizes the concurrent concept development process of RIM parts, was developed.

The next steps in the research will be to validate the framework by means of the prototype production and test on a company to be selected.

Although there is previous research works in the use of ES in product development, gaps were found concerning the lack of research in the concept development stage and lack of integration with other methodologies. Therefore, this research contributes to the existing literature on two levels 1) by studying the application of an ES in the conceptual stage of RIM parts development and 2) the ES's integration with PBCM methodology.

Rui Carreira	Portugal	LTI	FEUP
Starting year 2007	Estimated date of Completion 9/2011	Year of PhD 4 th	Amount of time spent at MIT 1.5 months
Title of the thesis <i>Designing the Travel Experience</i>			

Supervisors

in Portugal: Lia Patrício (FEUP), Renato Natal (FEUP)
at MIT: Chris Magee

References of the three best publications on PhD research

“Towards a holistic approach to the travel experience: a qualitative study of bus transportation”, to be submitted to the Transportation research journal

Research progress and major scientific contributions

Designing for the customer experience is increasingly important for the success of new product development (NPD), but two challenges arise: First, the customer experience is determined, not only by the product, but also by the interaction with service(s) within which it may be embedded. Second, the customer experience is formed in all moments of interaction with a product or service. Specifically in public transportation, the travel experience (TE) provided is holistic in the way that it starts before the actual trip and doesn't necessarily stop after arriving at the destination. The Kansei engineering method allows for the incorporation of affective reactions and emotions in NPD, but it does not involve a structured and holistic approach to the study of the customer experience.

This project aims at better understanding customer TEs and to develop methods for incorporating their requirements in NPD. In order to identify customer TE requirements, qualitative and quantitative studies were performed with bus users in two settings: tourism and inter-city. The qualitative study consisted of observations and interviews with 25 tourists and 27 inter-city passengers that were fully transcribed and their content analyzed. The quantitative study was based on two questionnaires that were self-administered by 188 tourists and 1596 inter-city passengers. The data was analyzed following standard procedures for scale development, involving exploratory and confirmatory factor analysis, and structural equation modeling. The study results identified 7 dimensions of TE requirements (Individual Comfort, Information provision, Driver's skills, Social Environment, Bus maintenance, Bus terminal, Ticketline service). The Bus Interior Aesthetics is associated to the dimension of overall comfort, which the passengers rated as very important and also as having a low performance in current buses. The translation of the Interior Aesthetics-ER into bus body design parameters was done using the principles of Kansei Engineering Methodology with the collaboration of a bus body manufacturer and MIT researchers. Additionally, the period at the MIT was important to contact with researchers working on NPD.

So far, with the collaboration of the transportation companies involved, it was possible to have an in-depth understanding of the TE, based on experience-centric (i.e. tourists) and utilitarian (i.e. inter-city) passengers' perspective, and contribute to a more holistic incorporation of the TE in the NPD process. Additionally, the design of new vehicles and transportation services as an integrated whole is improved by the use of an adequate affective oriented engineering methodology to incorporate the better understanding of the passengers' TE requirements.

Sérgio M. O. Tavares	Portugal	LTI	FEUP
Starting date 2007	Expected date of completion 2011	Year of PhD 4 th	Amount of time spent at MIT 6 months

Title of the thesis

Design and Advanced Manufacturing of Aircraft Structures using Friction Stir Welding

Supervisors

in Portugal: Paulo de Castro (FEUP); Pedro Vilaça (IST)
at MIT: Thomas Eagar

Main Publication

S.M.O. Tavares, et. al., ‘Friction stir welding of T-joints with dissimilar aluminium alloys: mechanical joint characterisation’, Science and Technology of Welding & Joining, Vol. 15(4), May 2010 , pp. 312-318.

S.M.O. Tavares and P.M.S.T. de Castro, ‘Impact of Integral Structures in the Design for Manufacture and Assembly of Airframes’, Key Eng. Mats, 2011, Vol. 450, pp. 279-282.

P.M.G.P. Moreira, T. Santos, **S.M.O. Tavares**, V. Richter-Trummer, P. Vilaça, P.M.S.T. de Castro, ‘Mechanical and metallurgical characterization of friction stir welding joints of AA6061-T6 with AA6082-T6’, Materials & Design, Vol. 30(1), Jan. 2009, pp. 180-187.

Research progress and major scientific contributions

The design of aircraft structures depends upon multidisciplinary factors that must be analyzed concurrently in order to achieve higher degrees of optimization and economy of production. As an example, the introduction of advanced manufacturing processes for structural joining requires a detailed understanding of the mechanical behavior of the joint under service conditions, whilst simultaneously requiring analysis of the manufacturing, assembly, operation and maintenance procedures. The case of friction stir welding (FSW) was chosen since it is the object of large interest for structural joining by manufacturers of commercial aircraft and aerospace equipment. The development of new designs and manufacturing concepts and the understanding of the effects of replacing previous joining processes have been analyzed, taking into account distinct technological and economic aspects during the product and process development, thus creating opportunities for better acceptance. Several topics were explored as a result of the interaction with different universities, research institutes and industrial collaborations, giving an expanded analysis of the problem.

Research results include analysis of the impact in the replacement of joining processes in safety critical structures, mechanical characterization of the joints manufactured with FSW, analysis and modeling of the residual stress originated by the process, examination of main flaws and non-destructive techniques to detect them, investigation of the application of this process in fuselage assembly, cost and weight analysis and a final technology assessment based on the design for manufacturing and assembly assumptions. Through this research, two patents applications were submitted with new concepts for the use of this joining process in aeronautical structures, one of them in the scope of the internship at Airbus. The results indicate that the FSW alternative is certainly viable in terms of costs and weight savings, and, with limits to be stated in this thesis, is also suitable as far as fatigue behavior is concerned.

2.3.Sustainable Energy Systems

2.3.1. Overview

The Sustainable Energy Systems PhD program (SES), promoted by a set of Universities in Portugal, namely the Technical University of Lisbon (Instituto Superior Técnico – IST and Instituto Superior de Economia e Gestão – ISEG), University of Coimbra (Faculty of Sciences and Technology and Faculty of

Economy), University of Lisbon (Faculty of Sciences - FCUL) and University of Porto (Faculty of Engineering, FEUP) and with the collaboration of MIT, is a unique effort to generate new knowledge of clean energy systems that is academically rigorous as well as highly relevant to policy makers and industry.

The program was designed around the concept of energy systems as opposed to specific energy *technologies* because the real challenge behind developing an advanced, low-carbon energy future will be integrating and adapting a range of technologies to a dynamic regional context. To this end, the SES has developed education programs to provide students with the tools to understand and evaluate complex energy systems, as well as research programs to facilitate opportunities for students to apply these skills in a real-world context.

Three unique and essential aspects of the SES program include our multidisciplinary approach to energy education and research; the direct utility of our research for improved policy and industry development; and the opportunity for applied research of integrated energy systems. Rather than discuss each of these key program components conceptually, it is more useful to view the value of each of these aspects through some of the innovative research topics developed by our PhD students in a collaborative effort within their home universities, and through their extended research stays at MIT.

A multidisciplinary approach

The SES educational program is anchored by a multidisciplinary core curriculum. Students learn to approach complex energy challenges by leveraging tools from the fields of economics, engineering, policy analysis and management, among others. While dissolving disciplinary boundaries within a single university represents challenge enough, the SES program was able to develop a coherent multidisciplinary program across *multiple* universities in Portugal and in coordination with MIT. This collaboration has created a platform for students to define unique and novel energy research topics, often at the nexus of two or more disciplines.

One of our third-year PhD students is working at the interface of architecture and energy efficiency engineering. During his classroom research, he recognized that the architectural demand for the aesthetic at the early stage of building design was completely disconnected from designing building shape to maximize energy efficiency. In response, he is developing a tool for optimizing building shape to balance architectural vision with key energy efficiency objectives.

Of course, addressing new buildings alone is not sufficient to reduce the environmental burden of the building stock. Other students are focusing on improving energy use in existing buildings by developing a multi-objective optimization tool to inform choices about the retrofit options. Also, linking multiple disciplines, their models balance economic, environmental, and thermal comfort metrics to inform retrofit design.

Advances in Information and Communication Technology (ICT) are being leveraged to enable energy efficiency monitoring and management in a promising research effort. The students are seeking to understand what types of information, data processing and communication are necessary to make an electricity grid “smart” from the standpoint of increasing the efficiency of end-uses. Their approach includes research from the fields of energy demand monitoring, consumer behavior and artificial intelligence.

Policy and industry relevance

As an academic program, the SES focus recognizes the fundamental requirement of any PhD research, namely that it must generate new scientific knowledge. However, our program goes a step further. We push our students to select topics that encourage them to create knowledge that can be applied directly towards the development of advanced energy systems, through either policy or industry channels.

Three fourth-year PhD students are finalizing high-quality research on policy-relevant topics. Recognizing the emergence of city leaders as key players in the energy policy arena, a student has focused her research on reviewing and consolidating metrics for sustainability to assist policymakers at the local level. She has already applied these metrics to two case studies: Porto (her home research city) and the City of Boston (during her extended research stay at MIT). Another student has approached the policy dilemma of balancing the liberalization of electricity markets while simultaneously promoting renewable electricity generation. Specifically, she is developing a methodology to optimize renewable energy feed-in tariffs to minimize carbon emissions while maximizing the influence of market forces to increase the economic efficiency of the system. In a third topic, a student's research addresses the effects of transportation policy on automobile fleet composition, and the subsequent impacts on energy consumption, CO₂ emissions and total cost. Rather than creating a "black box" optimization model, she has developed a simulation model where decision-makers are given the power to compare alternative scenarios to match their particular policy targets.

Meanwhile, a third-year PhD candidate is assessing the economic and environmental sustainability of biofuels from vegetable oils encompassing the whole life cycle of the systems analyzed, including policy-relevant local impacts such as deforestation, water pollution, and land use competition with food crops. The recent EU Directive 2009/28/EC and EPA's Renewable Fuel Standard Program show the importance that policymakers are attributing to this topic both in Europe and the US.

The SES Program has three fourth-year students working at highly industry-relevant themes. One topic is based on identifying a clear set of metrics for corporate sustainability. The student is working to develop a set of key sustainability performance indicators that can be applied widely for sustainability benchmarking and performance assessment of corporations. On the more technical side, two students are working collaboratively to analyze the potential impacts of large-scale introduction of electric vehicles (EVs) on the power network. These students recognized early on that the major challenge in the transition to a clean energy future is not the development of individual technologies (such as EVs), but the *integration* of new technologies into the existing system infrastructure.

As an example of student research linking tightly with industry, a fourth-year student is developing a patented technology to strongly reduce the cost of photovoltaics (PVs) – cost being the main barrier for massive penetration of PV panels into the energy market. He is now refining his technology design in an MIT laboratory and his innovative design has already formed the technological core of a new startup company founded by Portuguese researchers.

Integrated energy systems applied research projects

In terms of applied energy research, the SES Program has developed two major research projects that seek to integrate many of the individual student research topics and apply them to a real world energy system. The Green Islands Project focuses on developing a set of advanced energy systems modeling

tools, including renewable resources and demand side management, that are applied to promote a sustainable energy future of the Azores archipelago, and the Sustainable Urban Energy Systems topic analyzes the many dimensions of the Lisbon and Porto energy systems.

A key focus of the Green Islands project is to develop an in-depth understanding of the dynamic energy supply and demand system on each of the nine islands. Since each island represents a small, isolated energy community, small perturbations or interruptions in either the fuel or electricity systems have a relatively greater impact than on large networked systems in the mainland. As the Azores moves towards a higher penetration of renewables in the electricity generation in the islands, a higher resolution monitoring and management system will need to be deployed to actively balance increasingly complex supply and demand pressures.

On the supply side of our Green Islands Project research, a fourth-year student is characterizing the complex patterns and probabilities of wind power production across all islands and all time scales (from hourly to annual). She has developed her research project while studying at both in Portugal and MIT, as well as in collaboration with researchers in the Azores at the local university. Her research will produce invaluable analysis for future development of wind resources in the Azores with specific contributions towards scaling and siting future wind farms. Focusing on solar resources in the islands, a third-year student, whose research is partly financed by a Portuguese industrial photovoltaics company is testing a low concentration photovoltaic system in the Azores.

Another student is focusing his research on demand-side energy analysis with specific emphasis on developing a multi-criteria decision-making platform for targeting end-uses best suited for efficiency interventions, and then quantifying the effects of these policy measures in terms of energy and cost savings. His research will culminate in the development of an Energy Efficiency Action Plan for the Azores region.

The Sustainable Urban Energy Systems project operates on the thesis that the concentration of resource and material flows through urban centers represents both a challenge and an opportunity for the advancement of sustainability. By closely examining and characterizing these resource flows, researchers can highlight key entry points for efficiency measures or “closed-loop” material conservation interventions. With ongoing rapid urbanization occurring globally, refining the resource “metabolism” of cities will play a key role in transitioning towards a sustainable future.

Using Lisbon as a case study, a fourth-year PhD candidate has focused specifically on creating a set of standard methods for analyzing urban material flows. He is working to re-characterize “static” standardized resource data sets into dynamic urban flows by developing a model that incorporates key additional parameters, such as material type categorization, resource conversion factors and lifespan calculations. With 80% of the 11 million tons of material inputs to Lisbon categorized as non-renewable resources, he aims to link his research directly to improved government policy as well as new space for industrial activity.

Another student is applying integrated econometric methodologies with spatial analysis (GIS) to map the geographic distribution of material flows across the city of Lisbon. This innovative multi-method approach will allow decision-makers and urban planners to visualize resource flows across the cityscape in terms of total flows and by individual sectors.

A bright future

The Sustainable Energy Systems Program began with a vision of an integrated education and research program designed to address the critical challenge of transitioning energy systems towards sustainability. Despite the occasional difficulty of coordinating a program of such breadth and ambition, the work produced by our students highlights the real success of our program in terms of developing innovative methodologies for energy research and preparing a cohort of future professionals that are well positioned to design and deliver an advanced energy future in Portugal and beyond.

Coordinators of Sustainable Energy Systems

António Gomes Martins, Faculty of Sciences and Technology, University of Coimbra

António Vallera, Faculty of Sciences, University of Lisbon

João Peças Lopes, FEUP, University of Porto (PhD director)

David Marks, Department of Civil and Environmental Engineering, MIT (PhD director)

Paulo Ferrão, IST, Technical University of Lisbon

2.3.2. Structure

The Sustainable Energy System doctoral program is a unified program for all the institutions involved in the SES program with a common core curriculum and common guidelines but with differentiated structures at a local level: FEUP (Porto), IST/ISEG/FCUL (Lisbon) and UC (Coimbra).

FEUP

The SES PhD program at the Faculty of Engineering of the University of Porto (FEUP) covers all the three areas of the SES research: Energy Planning, Sustainable Built Environment and Advanced Electric Networks. The first year is filled with courses and early preparation of the research plan, on which students work full time for another three years. The curricular plan of the first year is organized along three base graduation profiles:

Profile A: Energy Systems Planning

Profile B: Sustainable Cities and Regions

Profile C: Advanced Electric Networks

In each semester students must take 3 of the mandatory courses and choose 1 of the optional courses presented in Table below in order to complete a total of 60 credits.

Structure of the curricular part of the SES PhD program at FEUP (first year)

Course	Profile	ECTS	Mandatory/ Optional	Semester
Energy, Environment and Sustainability + thematic work	A,B,C	7.5	Mandatory	1st
Energy Planning	A,B	7.5	Mandatory	1st
Energy Markets and Regulation	C	7.5	Mandatory	1st
Analysis and Simulation of Thermal Systems	A,B	7.5	Mandatory	1st
Signals, Dynamics and Control	C	7.5	Mandatory	1st
Introduction to Economics *	A,C	6	Optional	1st
Economics of Natural Resources and Environment *	A,C	6	Optional	1st
Projects Evaluation and Externalities *	B	6	Optional	1st
Computational Intelligence and Power Systems	C	7.5	Optional	1st
Seminar	A,B,C	22.5	Mandatory	2nd
Energy Efficiency	A,B	7.5	Mandatory	2nd
Market Simulation	C	7.5	Mandatory	2nd
Energy Demand Side Management	A,B	7.5	Mandatory	2nd
Electrical Systems with Renewables	C	7.5	Mandatory	2nd
Optimization and Decision Support Techniques	A,C	7.5	Optional	2nd
Energy in Buildings	B	7.5	Optional	2nd
Forecasting	C	7.5	Optional	2nd
Methods for Optimal Power Flow	C	7.5	Optional	2nd
Wind Energy	C	7.5	Optional	2nd

* Modules offered by UTL/FCUL

UNL/FCUL

At the Technical University of Lisbon (UTL) / Faculty of Sciences of the University of Lisbon (FCUL), students have the opportunity to build a diversified curriculum with Economics and Policy courses at the School of Economics and Management (ISEG-Instituto Superior de Economia e Gestão from UTL) and Environment, Technology, and Systems modules at the School of Engineering (IST - Instituto Superior Técnico from UTL), and/or the Faculty of Sciences of the University of Lisbon (FCUL).

Each student in the Doctoral Program creates a unique curriculum to fulfill her/his individual interests. The students have two mandatory courses, Seminar I and Seminar II, and then choose from a pool of optional courses (Table below) under the supervision of a designated faculty member, in order to complete 48 to 60 credits (ECTS).

Structure of the Sustainable Energy Systems PhD at IST/ISEG/FCUL

Scientific area	Course	ECTS	Mandatory/ Optional	Semester
Introductory courses	Introduction to Economics	6	Optional	1st
	Introduction to Engineering	6	Optional	1st
Economics	Economics of Natural Resources and the Environment	6	Optional	1st
	Econometrics	6	Optional	1st
	Energy Systems Economics and Modeling	6	Optional	1st
	Risk Management	6	Optional	2nd
	Projects Evaluation and Externalities	6	Optional	2nd
	Regulation Theory	6	Optional	2nd
Environment	Energy, Environment and Sustainability	6	Optional	1st
	Energy in Transportation	4,5	Optional	1st
	Ecological Economics	6	Optional	2nd
Energy Systems	Energy Management	4,5	Optional	1st
	Energy Systems Integration	6	Optional	2nd
	Optimization of Energy Systems	6	Optional	2nd
Energy Technologies	Seminars I	3	Mandatory	1st
	Seminars II	3	Mandatory	2nd
	Energy in Buildings	6	Optional	2nd
	Nuclear Energy	6	Optional	2nd
	Renewable Energy Resources	6	Optional	2n

UC

The students of the SES Doctoral Program at the University of Coimbra (UC) have to complete the 2 mandatory courses and they choose other courses from a pool of optional courses (see Table below) in order to sum up a total of 60 credits (ECTS) in their first year.

The program is divided into 2 areas:

Buildings and Urban Environment

Energy Systems and Policy

At the end of the first semester students should find a faculty member at their university who agrees to be their Faculty Research Supervisor. Faculty Research Supervisors should advise the students on their research paper. At the end of the first year, the Faculty Research Supervisor will be asked to write a letter of recommendation for the student, assessing his/her potential for carrying out a PhD thesis successfully.

At the end of the first year in the PhD program, students will be evaluated in order to decide whether they qualify to proceed to the 2nd year of the program. This decision will be made at their host university, taking into account a recommendation by the SES Committee (with a representative from all the Portuguese universities offering the SES PhD degree and a representative from MIT).

Structure of the SES PhD program at the University of Coimbra (UC)

Scientific area	Course	ECTS	Mandatory/Optional	Semester
Mandatory Courses	Research Design & Methods	3	Mandatory	1st
	Thesis project (includes the SES doctoral seminar)	30	Mandatory	1st and 2nd
Buildings and Urban Environment	Space organization and the Environment	6	Optional	2nd
	Buildings and Environment	6	Optional	1st
	Energy Management in Buildings	6	Optional	1st
	Indoor Environmental Quality	6	Optional	1st
	Seminar – Buildings and Urban Environments	3	Optional	2nd
	Ventilation, HVAC, and Building Systems	6	Optional	2nd
	Building Envelope - Outside Environment	6	Optional	2nd
Energy Systems and Policy	Energy Economics and Markets	6	Optional	2nd
	Environmental Economics	6	Optional	1st
	Energy Management in Industry	6	Optional	1st
	Seminar – Energy Systems	3	Optional	2nd
	Renewable Energy Systems	6	Optional	1st
	Transportation and Energy	3	Optional	1st
Other elective courses offered by UC	Decision Analysis	6	Optional	2nd
	Industrial Ecology	6	Optional	1st
	Fundamentals of Operations Research	6	Optional	1st
	Innovation & Entrepreneurism	3	Optional	2nd
	Measurement and Data Acquisition Systems	6	Optional	2nd
	Introduction to Energy Systems	6	Optional	1st
	Energy Planning and Sustainable Development	3	Optional	2nd

Common guidelines

In order to continue in the PhD Program, students must meet the following criteria:

- Complete enough courses in order to obtain the required number of ECTS at their host school,
- Complete the SES Doctoral Seminar,
- Obtain a minimum average grade of 14 (out of a 0-20 scale) at the end of the first year,
- Provide a recommendation letter from their Faculty Research Supervisor,
- Prepare a research statement of up to 4 pages with a brief summary of the state of the art that outlines the research area of interest, hypothesis, research methodology, strategy for the completion of the research, and provisional schedule.

Students who do not meet the minimum criteria described above will not be invited to continue in the PhD Program, but if they have sufficiently completed the coursework requirements for the first year, they will be awarded a diploma of an Advanced Studies Program (DEA or DFA). This will be determined by their host universities.

Each qualified PhD student will be assigned a PhD Committee. This committee is responsible for monitoring and guiding the student's progress through his/her research activities. Students should

meet with the PhD Committee at least once per semester. Students who will be conducting research at MIT will be required to have an MIT Faculty member on their committee.

At the completion of year 2, PhD candidates shall produce a Thesis Assessment paper of about 20-30 pages reporting the state of the art, selected research questions, formal definition of the problem to study and modeling, hypothesis and methodologies to tackle the problem, data collected or plans for it and definition of study cases, tools to be used and any preliminary results. Students will meet with their PhD Committee to present and discuss the progress assessment report and receive feedback. If the PhD Committee determines that the student is not making enough progress on his/her research, this will be discussed with the student and next steps will be determined.

2.3.3. Student highlight

A few students stand out from the Sustainable Energy Systems doctoral program because of the large number of publications in international conferences and journals they have made and also because of the outstanding quality of their work and the innovative contribution they brought to their field. These are:

Patrícia Baptista who developed the theme of the environmental impacts that may result from a large scale deployment of electric vehicles, namely the identification of pollutants emissions applying a vehicle full life cycle analysis. Patrícia spent some time at MIT: here is her comment about her experience there.

‘I spent seven months developing my research work at MIT in 2009. In terms of my research these were decisive to integrate it in the existing research and to have my co-supervisor contribution. The main positive aspects were the possibility to attend classes at MIT, great interaction with faculty and especially with my co-supervisor, the integration within MIT student’s community and the diversity of activities available on campus’.

Patrícia Baptista, IST

André Pina who developed multi-scale energy models with high time resolution, regarding supply and demand dynamics for the optimization of investment in new generation capacity. This led to a new application of TIMES, which main goal is maximizing the penetration of renewable energies. The test bed is the São Miguel island, at Azores. André has made a short but profitable visit to MIT and he describes below its outcomes.

‘The objectives of my short visit to MIT were to share my research in the modelling of sustainable energy systems and coordinate with the local Green Islands team in terms of data availability and possible research cooperation. From this trip I was able to contextualize my thesis topic in the broader scope of the ‘Green Islands Project’ and guide my research to areas where there is a lack of knowledge.’

André Pina, IST

Filipe Soares developed simulation tools capable of evaluating the impact of different Electric Vehicle charging strategies in the operation of electrical grids. He also developed a statistical approach for assessing the impacts resulting from EV presence in a given electricity network, taking into account the patterns of mobility in a certain geographical area. Filipe carried out part of his research work at MIT: here is his opinion about the time he spent there.

‘The time I spent at MIT provided me the opportunity to contact professors and students working in the same research area as me and the possibility of having important discussions with them about my thesis topic. As a result of these meetings, some partnerships were established with several MIT students for publishing articles in international peer-reviewed journals. The valuable contact with MIT's industrial partners that work in subjects related with my research area was also very useful, since it has deepened my knowledge about the process of transferring technology from universities to industry.’

Filipe Soares, FEUP

Pedro Almeida developed new control procedures to be adopted by electric vehicle battery / grid interfaces in order to make EV participate in primary and secondary frequency controls. Pedro developed some of his work at MIT: here is his opinion about this stay.

‘Being in Boston gave me the possibility of contacting with people whose research areas are complementary to mine, both in the academic side and in the university side. I met battery manufacturers and research groups conducting laboratorial fatigue tests to different battery technologies, subject of great importance for validating and assuring that the models I have developed for my thesis are in line with the current state-of-the-art.’

Pedro Almeida, FEUP

2.3.4. New courses and faculty involved

For the SES educational programs (PhD and Master’s) 38 new courses have been specially designed. These courses are taught by 50 faculty members from the 5 participating Portuguese schools in this area. The MIT faculty participates with guest speakers in doctoral seminars which take place throughout the year. In the last academic year (2009/10) 5 MIT faculty members gave 8 seminars of 2 hours each.

2.3.5. Use of open-source community-based tools for learning

At FEUP students use the local platform called SiFEUP where the faculty posts all the information about the classes, including grades. Students can use this platform to communicate with each other and faculty.

The main platform for interaction between students and faculty for the students at IST/ISEG is the Google groups. This platform has been in operation since 2008 and has currently 147 members, including students and faculty. It has a forum where the coordination posts conferences advertisements and important information about the courses daily activities, but also where students talk with each other about energy topics that they are studying. The Google group is also used to store information for each of the taught courses, in particular the syllabus, presentations, bibliography, faculty contacts. Important information like exams calendar, schedule, studies plan, course organizations and educational support documents are also stored here for students to have access. A new platform, using the Moodle system, is currently being developed to be used in the second semester because it has more capacity and functionalities, which are needed by a growing number of students.

Faculty is asked at the beginning of each semester to send the syllabus of the course that he/she will be lecturing and important readings for students to read beforehand. Each faculty is requested to send the PowerPoint presentations prior to the class. Important course information, evaluations, and other materials are always sent to the SES contact point at IST/ISEG, whom redistributes the information to all the students through the Google group or by email.

The main platform for interaction between students and faculty at the University of Coimbra is the Nonio web-based system (<https://infoestudante.uc.pt>), which has been developed by a university spin-off software company. The system requires authentication, by entering the student's e-mail login and password and it allows the student to:

- browse information about the courses (syllabus, objectives, etc.)
- browse schedule (calendar tool)
- browse information about their teachers (profile, office hours, etc.)
- have access to lesson summaries
- have access to class materials and notification about new materials inserted
- have access to grades and notifications about grades published
- receive and send messages (e-mail)

2.3.6. Benchmarking

The Sustainable Energy Systems (SES) program is an integrated educational initiative offered across six schools (IST, ISEG, FCUL, FCTUC, FEUC and FEUP) in Portugal and in collaboration with MIT. The SES program offers both a Master's of Business Engineering and a PhD in Sustainable Energy Systems. Both degree programs share a one-year (150 hours) cohesive core curriculum that includes classes in the disciplines of economics, engineering, and policy analysis as applied to energy systems.

Both programs challenge students to apply a systems approach to energy research with the ultimate objective of creating and applying knowledge for the design and implementation of sustainable energy systems. Participants have the opportunity to learn about the practical application of energy strategies through real-world case study research conducted in collaboration with industry partners. Both PhD and DFA graduates are able to develop the tools they will need to play leadership roles in implementing sustainable energy policy and developing new business opportunities clean energy space.

Benchmarking approach

Currently, there are no standard quantitative metrics available for benchmarking the Sustainable Energy Systems degrees (DFA and PhD) against similar integrated energy graduate education programs at other universities. Further, since SES is a relatively new program, it is not yet possible to accurately benchmark outputs (number of theses, mean time to graduate, published materials, citations, career development by alumni, etc.) against other programs with multiple years of data on their graduates. Finally, a lack of published information about what is happening in other programs makes it difficult to apply a consistent of criteria for program comparisons, such numbers of candidates (applied, enrolled and graduated), dropout rate, etc. As the program evolves, the potential for benchmarking will increase as more indicators become relevant and as we learn more about similar programs abroad.

That said, it is important that the role of benchmarking should not be overstated in terms of creating a myopic focus on unidimensional indices like numbers of research papers or citation indexes. These types of metrics can skew evaluation efforts towards rewarding small individual accomplishments when the broader objective of SES is to create integrated systems philosophy in energy research. Nevertheless, what follows is our attempt at an objective benchmark analysis based on the structure and course curricula offered by similar PhD and Master's level programs.

Existing Sustainable Energy Systems programs

There are many other programs offering both Master's and PhD degrees in energy-related research, but most of these initiatives do not include a structured educational program with the highly integrated, systems approach that is central to the SES Program. Internationally, the majority of programs being offered are Master of Science (MSc) degrees with heavy emphasis on engineering, with few universities offering PhDs or Master's specifically in Energy Systems.

To our best knowledge, the only Doctoral Program in Europe that resembles the SES program in terms of providing a multi-university, interdisciplinary approach to energy systems is the Joint Doctorate Program in Sustainable Energy Technologies and Strategies (core member universities include: Comillas Pontifical University; Delft University of Technology; and KTH Royal Institute of Technology in Copenhagen). Both the SETS and SES programs offer instruction in multiple disciplines, including the fields of economics, social sciences, environmental management, engineering, policy studies, and systems design. However, the SETS program resembles more of a consortium of partner universities that share their existing curricula, rather than an integrated program with a shared, custom-designed core curriculum on energy systems like that of SES program.

Other universities offering PhDs relating to Energy Systems analysis include Carnegie Mellon – CMU (Engineering and Public Policy Program with a specific focus area on Energy and Environmental Systems); the University of California at Berkeley (Energy and Resource Group); and MIT (Engineering Systems Division). In contrast to multi-university design of the SES and the SETS programs, these three programs all operate independently in terms of curriculum design and degree requirements (of course, there is collaboration between MIT and SES on research projects, but not in terms of an official joint curriculum). While these three programs emphasize integrated systems approaches to research in energy technologies and policy design, only CMU has a depth of technical expertise in power grids that can compare to SES or the SETS programs.

Similar to the unique qualities of the SES PhD degree, the SES Master's in Energy is innovative amongst its peers (other MSc programs) in terms of its multi-university structure. Further, the DFA students share the same core curriculum as the SES PhD students, allowing for cross-collaboration across the degree programs as well as between the universities. As a result, the DFA students are participating at a doctoral level of intensive instruction in the three main fields of energy study: Sustainable Energy Technologies; Energy Economics and Policy; and Smart Energy Networks.

The next table shows an effort to summarize the core characteristics of the SES programs for the Master's of Business Engineering and PhD degrees as compared to other energy programs (PhD and MSc. levels) using the structural dimensions as discussed above: highest degree offered; multi-university collaboration; consistent core curriculum; and level of competency in the fields of Sustainable Energy Technologies, Energy Economics and Policy, and Smart Energy Networks.

As shown in the next Table, the SES program has many characteristics in common with other energy programs but truly stands out in terms of being a multi-university collaboration that offers structured core curriculum at the PhD and Master's level with a depth of expertise in energy technologies, economics and policy, and power networks. While the alignment of multiple universities around a common education and research platform is an ongoing challenge, it remains an important and unique characteristic of the SES approach to energy studies and continues to hold great potential for future program development. Long-term relationships with faculty both within and across universities should

be further developed, especially pertaining to human resource development in Portugal, including the mentorship, development and retention of young faculty.

The Sustainable Energy Systems PhD and Master's degree programs target a strategic niche in energy education and research by applying a systems approach to energy challenges. The systems approach permeates all aspects of the SES program from curriculum design to student topic selection to large-scale applied research projects. It provides students with the confidence to perform effective analysis in the context of complexity and uncertainty, which are both universal characteristics of real-world energy systems.

Finally, while the SES program represents real innovation in energy education and research, it is still a very young program relative to its competitors. As the program evolves and matures, faculty participants should seek opportunities to engage with counterparts at other universities to share lessons learned as well as remain aware of the state-of-the-art in energy research internationally. In this way, the program can build its reputation in the broader research community as a leader in advanced energy systems research.

Structural Comparison of Energy Research Programs at Relevant Universities

Program	Highest Degree Offered	Formal Multi-University Collaboration	Consistent Core Curriculum	Sustainable Energy Technologies	Energy Economics and Policy	Smart Energy Networks
Sustainable Energy Systems	PhD	Yes	Yes	High	High	High
SETS (Comillas, Delft, KTH) Sustainable Energy Technologies and Strategies	PhD	Yes	No	High	High	High
Carnegie Mellon University Engineering and Public Policy	PhD	No	Yes	Med	High	High
Univ. of California - Berkeley Energy and Resources Group	PhD	No	Yes	High	High	Low
MIT Engineering Systems Division	PhD	No	Yes	High	High	Med
EPFL Engineering Systems	MSc	No	Yes	Med	Med	Med
ETH-Zürich Energy Science and Technology	MSc	No	Yes	High	Med	High
Imperial College Sustainable Energy Futures; Energy and Economics	MSc	No	Yes	Med	High	Low
Stanford University Management Science and Engineering	MSc	No	Yes	High	High	Low
Aalborg Sustainable Energy Engineering	MSc	No	Yes	Low	High	Low

Note: For the subject areas, the values of “high, medium and low” reflect estimates of technical expertise in these areas based on the listed research areas and course offerings on each university’s website.

2.3.7. Educational initiatives

2007-2008

The main initiatives between Portuguese Institutions and the MIT during 2007-2008 were focused in the development and implementation of both educational programs and research activities. The main accomplishments were:

- Open workshops in Lisbon (October - Program Launch; November - Energy Industry Workshop of 2007): introduced energy systems topics and goals to prospective partners, including the Portuguese energy industry.
- Research workshop in Porto (October 2007): introduced energy systems topics to the PhD students.
- A workshop in collaboration with the faculty and students took place in January 2008 under the invitation of the MIT to the AGS meeting in Boston.
- Frequent visits to Lisbon and Porto in the Spring of 2008: the MIT and Portuguese faculty further refined collaborative research and educational activities, and reviewed and selected applicants for SES PhD, post-doctoral and faculty positions.
- Talks at participating universities: Portuguese government sponsored workshops (e.g. EU, OECD): and with the assistance of Ciência Viva, several visits to grade schools to talk about energy efficiency, alternative energy supplies, environmental challenges.
- Several additional visits to MIT by Portuguese faculty and current PhD students for focused discussions between research and educational leaders regarding the details of the program, research topics, students and resources.

2008-2009

In 2008-2009, collaboration between universities in Sustainable Energy Systems focus area was centered on the organization of the 2nd PHD Program Research Integration Workshop in Lisbon, in November 2008, and the Education Workshop in Coimbra in June 2009.

A welcome student's ceremony took place on the 14th October in FEUP, which featured the participation of Prof. Eduardo Oliveira Fernandes, Coordinator of the SES Focus Area at FEUP; Professor Paulo Ferrão, National Director; Prof. João Peças Lopes, PHD Program Coordinator at FEUP and Prof. Jorge Vasconcelos from New Energy Solutions.

At IST/ISEG a Students Welcome Ceremony was organized on September 15th to help new students familiarize with faculty, courses and program organization.

On February 17th 2009, Coimbra hosted invited talks by Eng^o Francisco La Fuente Sanchez (President, Fundação EDP) and Prof Jorge Villar Ale (Pontifícia Universidade Católica do Rio Grande do Sul - Brasil).

Additional events were organized at University of Coimbra included:

- A seminar on energy audits in buildings, with Eng^o Paulo Santos (ContaWatt) as guest speaker on 20th of March 2009
- Invited talks on Negotiation, by Prof. Rudolf Vetschera (Faculty of Business, Economics and Statistics, University of Vienna) entitled, "Unfair strategies in the fair division of indivisible items" and "Integrating quantitative and qualitative methods in the analysis of negotiations" on the 27th and 28th March 2009
- Video-conference by the Prof. Philip Andrews-Speed, expert in Chinese energy issues, entitled "At these moments of international financial crisis, will China become the world banker for financing the global natural resources?" on 27th April 2009
- Two sessions regarding the theme "Innovation And Entrepreneurship In Companies" presented by Dr. José Alves (MARTIFER) and by Prof. José Basilio Simões (ISA) on the 15th April and 13th May 2009.

From February 2009 to July 2009, FEUP held a series of Internal Seminar presentations. They consist of 1-hour lunch sessions every other Wednesday at 13h. In each session, two students make a brief presentation of their research topic and evolution, followed by an open discussion fostered by the faculty.

A one-week visit to MIT, designed and delivered by MIT faculty, was created for the Advanced Studies students at IST and received very positive feedback from the students who participated.

In terms of education-industry relation, several affiliated companies participated in lecturing the SES Seminar I and Seminar II courses over the year and supported their employees to participate not only on the DFA course but also in the PhD course.

2009-2010

The interaction with the other Portuguese institutions was reinforced through the organization of the 3rd PhD Program Research Integration Workshop in Coimbra on October 10th, 2009. This was a highly successful opportunity for interaction with MIT for PhD students and faculty. The one-week Sustainable Energy workshop for IST Advanced Studies was once again offered at MIT and again, was considered very successful.

At IST/ISEG a Students Welcome Ceremony was organized on the 23rd September at IST-Tagus Park, to help new students familiarize themselves with faculty, the course curriculum and overall program organization.

A "Teach the Teachers" faculty-training workshop on developing pedagogical skills for "Improving Student Learning and Knowledge Retention" was given by Janet (MIT) at FEUP on the September 25th 2009.

A welcome student's ceremony took place at FEUP on October 7th 2009, which featured the participation of Prof. Eduardo Oliveira Fernandes, Coordinator of the SES Focus Area at FEUP; Professor Paulo Ferrão, National Director; Prof. João Peças Lopes, PHD Program Coordinator at FEUP and Eng. Pedro Sena Silva from Autosil.

On November 20th 2009, on Sustainable Energy Systems Master's students participated in the 1st MIT Portugal / Michael Page Career Advancement Workshop. This focused on career preparation topics, including CV design, motivation letter composition, and interview preparation, among others.

From November 24-26th, the MIT President, Susan Hockfield, visited Portugal. During her stay, the partnerships between Portuguese technical universities and MIT were further strengthened. As an example, as part of her visit, several research networks were launched, including two initiatives specifically on energy systems:

- a) E2Research Net, focusing on electrical mobility and smart energy systems
- b) Sustainable Cities, focused on the Sustainability and Urban Metabolism of cities.

All the schools co-organized a workshop on the topic of modelling for energy planning that took place in January 2010 at IST, Lisbon. The event brought people from industry (REN, CEETA-ECO) and other institutions (LNEG, DGEG, FCT-UNL). It was such a success that the program has confirmed a repeat of this workshop for 2011.

In March 2010, the DFA students from IST once again visited MIT. The students engaged in many discussions with MIT faculty, visited local energy companies in the Boston area and participated in the MIT Energy Conference workshops.

From March to June 2010, FEUP hosted a series of Internal Seminars presentations. These focused on student presentations and discussion in a research colloquium format.

On June 17th, 18th, 24th and 25th, the SES program offered a WoC session (Window on Companies), with the objective of promoting a discussion forum where companies and students would interact with industry leaders through presentations and discussion. The final aim of these sessions was to develop a stronger bond between energy sector industries and the SES program, demonstrating to both parties involved the added value that may be realized through enhanced interaction.

SES faculty and students participated in the CIÊNCIA 2009 event held in Fundação Calouste Gulbenkian between the 27th and the 29th of July, 2009. This is the major event in science and technology in Portugal with several high-level speakers and session moderators.

2010-2011

At IST/ISEG a Students Welcome Ceremony was organized on the 17th September at ISEG, to help new students familiarize with faculty, courses and program organization.

On November 22nd, the University of Coimbra organized the initiative "Students meet companies" (2nd edition). This was an opportunity for students enrolled in the MSc and the SES PhD programs, the faculty and many industry representatives to share ideas on energy research in the context of a posters presentation session.

On September 11th, the University of Coimbra hosted the Welcome Session and Inaugural Lesson for all new students of the Energy for Sustainability Initiative to introduce new students to the overall program structure and organization.

A welcome student's ceremony took place at FEUP on the October 8th 2010 which featured the participation of Prof. Eduardo Oliveira Fernandes, Coordinator of the SES Focus Area at FEUP; Prof. João

Peças Lopes, PHD Program Coordinator at FEUP; Professor Vitor Leal; Professor Feyo de Azevedo, FEUP Director and Eng. Ricardo Sá from Edifícios Saudáveis.

Following the success previous SES orientation and integration workshops, the 4th SES PHD Program Research Integration Workshop gathered the faculty and students from all universities engaged in the Sustainable Energy Systems focus area to introduce and integrate SES education and research initiatives.

On November 25th and December 16th, IST promoted the “Windows on Companies” (WoC) sessions, with Feedzai and Novabase companies presenting. Additionally, three appointed sessions with other companies will take place the March 17th, and April 14th and 21st.

For the third time, the DFA students of IST will have one-week of intensive classes and presentations at MIT, from 26th February to 6th March.

A continuation of the 4th SES PHD Program Research Integration Workshop will be made in University of Coimbra on the 23rd and 24th of March, focusing on the three main areas of research in the SES focus area. Students will have the opportunity to interact with 3rd and 4th year students and faculty around discussions of strategies for designing dissertation research.

2.3.8. PhD theses

This section shows the profiles of each student who has spent some period of time at MIT.

The home institution of each student is indicated on the first line as:

FCTUC – Faculty of Sciences and Technology - University of Coimbra

FCUL – Faculty of Sciences – University of Lisbon

FEUP – Faculty of Engineering – University of Porto

IST – Instituto Superior Técnico – Technical University of Lisbon

Ana Rita Neves	Portugal	SES	FEUP
Starting year 2007	Estimated date of Completion September 2011	Year of PhD 4 th	Amount of time spent at MIT 3 months
Title of the thesis			
<i>Methodology for energy sustainability assessment and planning at the local level</i>			
Supervisors			
in Portugal: Vítor Leal (FEUP); João Lourenço (IST)			

Main Publication

Neves A.R., Leal V. 2010, "Energy sustainability indicators for local energy planning: Review of current practices and derivation of a new framework", *Renewable and Sustainable Energy Reviews*, vol. 14, no. 9, pp. 2723-2735.

Research progress and major scientific contributions

At a first stage, the major scientific contribution was the development of a set of energy sustainability indicators to be employed at the local level. This involved an extensive literature review of existing sets of sustainable development and energy indicators, the application of selection criteria, and the testing of the indicators with the municipality of Porto, and then asking two energy agencies in Portugal as well as the City of Boston in the United States to calculate the indicators. The methodological guide developed for the testing stage constituted a valuable help for the local authorities once they could find step-by-step guidance. The methodology adopted led to the identification of 18 indicators. At a time where local authorities are recognized as being important actors for implementing sustainable energy policies, by initiatives such as the Covenant of Mayors or the Local Government Climate Roadmap, the indicators become an important tool to evaluate the progress towards the achievement of the goals as well as to help local authorities in the choice of the most effective actions in the context of local energy planning. This research work was presented in two international conferences and a paper was published in a peer-reviewed journal (Neves, A. R. & Leal, V. 2010). At a second stage, another major contribution of my work will be to develop a methodology for decision-aiding in local energy planning, by making use of energy modeling and multi-criteria evaluation techniques. For this, it was crucial to start by structuring the problem of local energy planning using a problem structuring method. The cognitive mapping technique was adopted in interviews with the local actors for the identification of the objectives. A literature review of objectives, attributes and measures stated in local energy action plans and journals' articles was also carried out. The methodology has started to be applied to a Portuguese municipality as a case study, for which the task of energy modeling for the base year 2008 and for the time horizon of 2020 was accomplished. The expected result of the application of the methodology will be to provide support to decision-making in local energy planning processes, through the identification of the set of measures that better satisfies the objectives of sustainable energy planning for a given local context.

Daniel Wiesmann	Switzerland	SES	IST
Starting year 2008	Estimated date of Completion March 2012	Year 3 rd	Amount of time spent at MIT 11 months

Title of the thesis

Econometrics in Urban Metabolism

Supervisors

in Portugal: Paulo Ferrão (IST)
 at MIT: John Fernández (MIT)
 at Carnegie Mellon University, Pittsburgh, USA: Inês Azevedo

Main Publication

Daniel Wiesmann, Inês Azevedo, Paulo Ferrão and John Fernandez. *Residential Electricity Consumption in Portugal: Findings from top-down and bottom-up models*. Under revision in Energy Policy.

Research progress and major scientific contributions

The first study analyzes the influence of socioeconomic factors, dwelling characteristics and urbanization on residential electricity consumption per capita in mainland Portugal for 2001 using multivariate ordinary least squares regression analysis. The analysis is performed on two different scales, on the individual household level and on the municipal level. In the field of residential electricity consumption modeling this is the first study that directly compares results on both scales. The results indicate a significant influence of the tested socioeconomic variables, dwelling characteristics and urbanization on consumption. The consumption of electricity is found to be income inelastic with an estimated elasticity of 0.128. This has implications for policy formulations, indicating that other factors than just monetary constraints will have an important influence on future consumption.

The second study conducted so far is focused on providing spatial resolution to the analysis of GHG emissions at an urban environment and characterizes land cover change induced greenhouse gas emission in the metropolitan area of San José in Costa Rica. The land cover model is developed using multinomial logistic regression, as well as using a Bayesian maximum likelihood classifier. Data sources for the analysis are Land Sat images from 1989 and 2001 and relevant terrain and climate information. In the realm of satellite image classification, multinomial logistic regression has found little application and this study contributes to the introduction of that method into the field. Furthermore the land cover change modeling is not often used to calculate urban GHG emissions, and has never been developed for the study area.

In the second half of this PhD the objective consists of combining econometric modeling and spatial information and will be applied in a spatially explicit MFA model for Lisbon using bottom-up data sources. This is an innovative approach and will allow disaggregating flows by sector and with some spatial resolution. In urban metabolism there are only a few studies that use advanced statistical tools and include a spatial component into the analysis.

Filipa Amorim	Portugal	SES	IST
Starting year 2007	Estimated date of completion 2013	Year of PhD 4 th	Amount of time spent at MIT 1 week
Title of the thesis <i>Promoting renewable electricity whilst stepping into liberalized markets. An evaluation of the FIT in Portugal</i>			

Supervisors

in Portugal: Victor Martins (ISEG), Patrícia Silva (FEUC), Jorge Vasconcelos (IST):
at MIT: Steve Connors

Main Publication

Amorim, F.; Martins, M.V.M. ; Pereira da Silva, P. ; “A new perspective to account for renewables impacts in Portugal”; Energy Market (EEM), 2010 7th International Conference on the European Print ISBN: 978-1-4244-6838-6 doi: 10.1109/EEM.2010.5558695, August, 26th 2010.

Amorim, F.; Martins, M.V.M. ; Pereira da Silva, P.; “Innovative regulatory insights: the renewables incentive design in the Portuguese scenery”; Enerday 2010, April, 8th 2010.

Research progress and major scientific contributions

The present incentive for renewable capacity is mostly determined by the level of guaranteed feed in tariffs (FITs), what makes it mostly autonomous from total electricity demand. Higher FITs entail higher generation levels that cover higher shares of demand. Only the remaining demand is satisfied in the market. If the market is already small, such as in the Portuguese case, lower demand can cause competition to decrease due to lower trading volumes.

FIT systems have been relatively successful in deploying renewable production in the current decade, but consequently costs have been increasing in the electricity system. As renewable electricity prices are generally higher than the reference acquisition price the supplier of last resort would be paying for the same amount of power in the market, over costs emerge. Ambitious targets for renewable capacity have been set by the government by 2020 and, with these, over costs are expected to continue growing.

In an era of progress in the integration and increased competitiveness of MIBEL, a new methodology to assess over costs, *ex-post*, has been proposed by calculating the sum of the differences of renewable electricity prices and hourly electricity reference acquisition prices weighted by renewable production. Actual extra costs of “compulsory” hourly purchases of renewable power were compared to the alternative to acquire it in the market, bringing some flexibility into the current remuneration model, while preserving the stability of the expected FITs to renewable investors. This flexibility is particularly important as renewable sources vary erratically. Results from the applied methodology to 2008 and 2009 data show that FITs were set too high in the new market framework and that each consumer would have avoided paying an additional subsidy of approx. 3.2€/MWh in 2008, and, in 2009, of approx. 7.9€/MWh, if FIT were set to provide investors the same previously expected profitability.

In face of the new technical, economic and regulatory challenges, this research will bring insight to policy makers and to the regulator as it discusses how to efficiently accommodate growing shares of renewable power generation and intends to present a new methodology to estimate an optimal tariff design. This is a decision support mechanism for low carbon electricity markets that also takes part in the medium to long-term generation capacity investments choices, therefore, meaningful to utilities which look for the successful repayment of their investments.

Filipe Soares	Portugal	SES	FEUP
Starting year	Estimated date of	Year of PhD	Amount of time spent at MIT

Title of the thesis*Impact of V2G Systems in Grid Operation and Expansion***Supervisor**

in Portugal: João Abel Peças Lopes (FEUP)

Main Publication

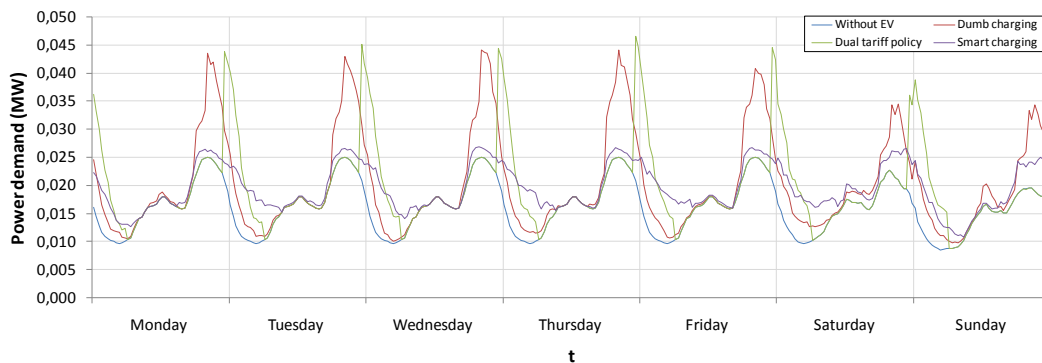
J. A. Peças Lopes, F. J. Soares, P. M. Rocha Almeida, "Integration of Electric Vehicles in the Electric Power System", Proceedings of the IEEE, vol. 99, no. 1, pp. 168–183, Jan. 2011.

Research progress and major scientific contributions

This thesis aims to provide a valuable study about Electric Vehicles (EV) and Vehicle-to-Grid (V2G) related approaches, which intends to alert all potentially interested parties for the various problems that will appear when EV start to be massively connected to the grid. Beyond the problems, it tries to develop adequate grid operation strategies, in a steady-state framework, to overcome all technical issues identified. To accomplish the referred objectives, it was first developed a conceptual framework for EV integration into electric power systems, providing a holistic perspective of this new reality with special attention on the electricity markets operation and on the networks technical management. This conceptual framework was developed taking into account the specificities of all the possible EV charging modes (dumb charging, multiple tariff policy, smart charging and V2G).

To successfully evaluate the impacts and benefits of adopting the previously mentioned EV charging modes, a simulation platform based in a stochastic method to simulate EV movement during one typical day, week or year and in a Monte Carlo method was developed. This computational application, allows performing a realistic evaluation of the steady state operating conditions of the grid, as well as identifying the network components that are subjected to more demanding conditions and that might need to be upgraded.

In order to evaluate the simulation platform performance, several networks and EV scenarios were tested. The power demand changes in a typical LV network with 30 conventional vehicles, 30% of them electric, are presented in the next figure. These results are referred to three EV charging scenarios: all EV in dumb charging mode, all EV in multiple tariff policy mode and all EV in smart charging mode. For the scenario that considers the multiple tariff policy, the period of lower energy price is between 23h and 6h, every day of the week.



Gustavo de Souza	Brazil	SES	FEUP
Starting year 2007	Estimated date of Completion 12/2011	Year of PhD 4 th	Amount of time spent at MIT 6 months
Title of the thesis <i>Contributions to demand energy planning by selecting the most efficient physical measures when building an Energy Efficiency Action Plan in a multi-criteria environment</i>			
Supervisors in Portugal: Vítor Leal (FEUP) at MIT: Stephen Connors			
Research progress and major scientific contributions My work can be divided into three main stages. The first stage is the development of a methodology to disaggregate national or regional energy systems into the most representative end-uses within domestic, service, industry and transport sectors. The first part of the work is already done. The second part of the work is related to find relevant criteria that represent the general interests from decision makers when building an energy efficiency plan. At last, the work proposes a tool where the national or regional energy system can be modeled and projected into the future, energy efficiency measures can be applied and their outcomes can be quantified and evaluated. The tool is already under development using MATLAB®.			
The major contributions are: A method to quantify and do the breakdown of the main energy end-uses found in the sectors of the economy. Also, using this method, a way to consider (use and quantify) a huge amount of EE measures (physical basis) reflecting the different sectors, end-uses and carriers. Another contribution is to evaluate alternatives to build a energy efficiency action plan (several sectors and several energy carriers) using a MCDA approach.			

Joana M. Abreu	Portugal	SES	IST
Starting year 2007	Estimated date of completion 2011	Year of PhD 4 th	Amount of time spent at MIT 11 months

Title of the thesis

Uncovering the potential for demand response in the residential sector

Supervisors

in Portugal: Jorge Vasconcelos, Francisco Câmara Pereira, Paulo Ferrão
 at MIT: David Marks, Stephen Connors
 at Carnegie Mellon: Inês Azevedo

Main Publication

Abreu, J., Câmara Pereira, F., Vasconcelos, J. Ferrão, P. (2010) *An approach to discover the potential for demand response in the domestic sector.* IEEE Conference on Innovative Technologies for an Efficient and Reliable Electricity Supply. Waltham-Boston, 27-28 Sep., USA.

Abreu, J. Azevedo, I., Câmara Pereira, F. (2011) *A contribution for a better understanding of the residential sector electricity demand.* European Council for Energy Efficient Economies (ECEEE) Summer Study 2011. Peer Reviewed. *In Press.* 6–11 June, France.

Research progress and major scientific contributions

The present research is centered on the residential consumer of electricity and is based upon experimentation and knowledge discovery. Following experimental design methods, a smart meter experiment involved participants from the Municipality of Oeiras (treatment and control), with the primary objective of accessing the effects of feedback and social pressure in residential electricity consumption in Portugal.

Secondary objectives include studying routine behaviors, and using clustering and segmentation techniques to characterize the population involved in the experiment. The experiment is designed to include one of the most effective drivers of behavioral change: social pressure and the need for humans to adjust and follow the norm. Additionally, it enables an opportunity to analyze residential load profiles and to identify those characteristics of demand that combined with the time of use and lifestyles of the individuals may indicate the potential for demand response.

Achieving the potential of energy efficiency and conservation on the residential sector remains to be a challenge. That is partly because society is increasingly dependent of electrical appliances and development is associated with consumption of goods and of commodities. Infrequent billing, low energy prices, and an increasing dependence of electricity all contribute to the current situation of generalized lack of interest with energy consumption in everyday decisions. Adding to that fact, decisions made in the house lack the medium to long-term foresight that implies that larger investments in the present will pay off in energy savings in the future. Such behaviors, easier to replicate in the home, but often not representing the way people take decisions at work, reveal hyperbolic discount rates. In a carbon constrained future, restricted by uncertain supply security energy efficiency in the residential sector starts to be perceived, by utilities and politicians as a supply option (megawatts). Yet its real potential lacks to be established. The experiment has ended in September 2010, but preliminary results are already being prepared for publishing.

Kiti Suomalainen	Finland	SES	IST
Starting year 2007	Estimated date of completion 8/2011	Year of PhD 4th	Amount of time spent at MIT 6 months
Title of the thesis <i>Wind speed dynamics in synthetic wind speed scenarios for energy systems modeling</i>			

Supervisors

in Portugal: Paulo Ferrão (IST), Carlos Silva (IST)
at MIT: Stephen Connors

References of the three best publications on PhD research

K. Suomalainen, C. Silva, P. Ferrão, S. Connors, 2011, Synthetic wind speed scenarios including diurnal effects: Implications for wind power dimensioning. Submitted to Energy: Special Iss. Advances in Energy Studies in January 2011.

K. Suomalainen, C. Silva, P. Ferrão, S. Connors, 2011, A method for including diurnal effects into synthetic wind data for energy systems planning: Validation in the Azores islands. Submitted to Renewable Energy in October 2010, under revision.

Research progress and major scientific contributions

The research is focused on wind dynamics through a methodology has been developed to design synthetic wind speed scenarios taking into account the resource's natural variability at hourly, daily, seasonal and annual temporal scales. The methodology includes diurnal effects of the wind, which in turn allows the quantification of surpluses and shortages of wind power in different wind regimes. This is particularly important to design high penetration wind energy systems such as in islands and constitutes the main contributions of the present research.

The current research presents a new methodology for taking into consideration the variability of a renewable energy resource, wind, at different temporal scales (hourly, daily, seasonal, annual) in generating scenarios for energy systems modelling, which is critical to design of high wind energy penetration energy systems. It is argued that Markov models and auto-regressive (moving average) models, generally used for synthetic wind speed data generation, do not contain sufficient low frequency information related to seasonal and diurnal wind patterns, especially for small and medium sized energy systems. Under high penetration wind scenarios, the daily pattern of the wind, as well as its magnitude, become increasingly important to energy system modelling and design. This new methodology is applied to various locations in the Azores, Portugal, to evaluate the impact of diurnal effects on wind power dimensioning and to quantify surpluses and shortages during different periods of the day. Statistical analysis indicates that there are strong seasonal differences in both the magnitude and shape of the wind within a given day that will affect energy system design and performance. The methodology being developed evaluates the frequency of different wind day-types, such as afternoon winds or morning winds, along with the magnitude of wind for varying locations in the Azores with different quality wind resources. The data used represents three location types: coastal, mid-island and offshore locations in the Azores archipelago. Application of the new methodology indicates that the inclusion of diurnal wind characteristics for the analysis of future energy systems provides better design information, especially as it pertains to generation investment requirements to meet island specific renewable penetration targets, and intra-day surpluses or shortages of wind generation in small energy networks.

Leonardo Rosado	Portugal	SES	IST
Starting year 2007	Estimated date of Completion	Year of PhD 4 th	Amount of time spent at MIT 1 month

August 2011

Title of the thesis

Urban Metabolism: Contributions to establish standard methods to analyze Urban Material Flows

Supervisors

in Portugal: Paulo Ferrão
at MIT: John Fernandez

Main Publication

Niza, S., **Rosado, L.** & Ferrão, P. 2009. Urban Metabolism Methodological Advances in Urban Material Flow Accounting Based on the Lisbon Case Study. *Journal of Industrial Ecology*. Volume 13, Number 3. 384-405.

Research progress and major scientific contributions

Urban areas have become one of the main focal points to tackle sustainability problems. The urban metabolism of a city depends on anthropogenic and natural physical flows of energy and materials, what might be studied by Material Flow Analysis (MFA). The work developed makes a contribution in the field of Urban Metabolism, by providing a standard method to measure the MFA that can be applied to different Urban areas, namely in European Countries. By analyzing Urban areas in detail the contributions of this research work to the MFA methodology relate to the identification of specific characteristics of flows in the Urban context opposed to country wide economies. An important contribution is the identification of key data sets and how to use them in order to analyze an Urban MFA to characterize products and goods into material types, lifespan, economic activity origin and destination, among others. It also includes establishing a link between flows and environmental impacts, a field still being developed in the MFA theory. A first model for flows of resources in the Lisbon city was built, and the link between MFA and environmental impacts was analyzed by accounting the household consumption of goods and measuring its embodied energy. Some results are: Lisbon city material inputs were 11 million tons in 2004, about 7% of Portugal material consumption; Total outputs are 2.149 million tons. More specifically, Non-renewable material resources represent almost 80% of the total material consumption. In preparation is an MFA for the Lisbon Metropolitan area. The effort put on developing a better methodology for Urban MFA aims at providing better answers to urban planners and companies that deal with resource management. By providing more detailed information about flows of resources, for example better waste or energy management policies can be applied.

Maria Kapsalaki	Greece	SES	FEUP
Starting year 2007	Estimated date of Completion 09/2011	Year of PhD 4 th	Amount of time spent at MIT 8 months
Title of the thesis <i>Strategies for the design of Net Zero Energy Buildings</i>			

Supervisors

in Portugal: Vitor Leal
at MIT: Leon Glicksman

Main Publication

M.Kapsalaki, V.Da Silva.Leal An assessment of the influence of the climate in the design of net zero energy buildings. PALENC 2010, Rhodes Island, Greece, September 29 to October 1, 2010

M.Kapsalaki, V.Da Silva.Leal Recent Progress on Net Zero Energy Buildings. Submitted to Journal of Advances in Buildings Energy Research Vol 5, 2011: ISSN: 1751-2549 E-ISSN: 1756-2201

Research progress and major scientific contributions

My PhD thesis is related to residential Zero Energy Buildings in respect to climate and resource diversity. At the moment a software tool is being developed in MATLAB that based on a given geometry type and geographical location, determines the energy needs, flows and a life cycle economic analysis for many envelope, energy services and local offset equipment while next steps involve the testing and application of the software- tool and the development of an optimization algorithm. So far, the tool is able to perform the annual final energy needs calculation which is based on the RCCTE calculation methodology (the Portuguese regulation that measures the thermal performance of buildings); the RCCTE method is a steady state method based on the heating degree days (HDD). The tool takes as input parameters that characterize the building envelope, the energy services and micro-generation equipment and the economics. More specifically as regards the building envelope the input required includes the: useful area, shape factor, height, adjacent area, internal area, insulation levels for the roof and the walls, inertia, infiltration, window type, shading, ventilation and orientation; regarding the equipment providing the energy services and the micro-generation ones the input related involves the heating system, cooling system, domestic hot water system (DHW), lighting, electric appliances, type of photovoltaic (PV) module and wind turbine; finally the economics related input covers the costs for insulation, windows, shades, heating cooling and DHW systems, electric appliances and micro-generation systems. Besides the calculation of the energy needs the tool sizes the micro-generation equipment needed to offset the consumption, as well as the heating, cooling and DHW systems and can give an estimation of the initial cost. At the moment an optimization algorithm is under development which will analyse all the possible combinations of the input parameters and give the optimum solution regarding the following: lowest initial cost, lowest yearly energy bill and lowest cost in a life cycle of 10 and 20 years. The final step of the research will be to test and apply the software-tool for different geographical locations and different types of buildings.

Marta Mota	Portugal	SES	FEUP
Starting year 2007	Estimated date of Completion 7/2011	Year of PhD 4 th	Amount of time spent at MIT 12 days

Title of the thesis

Corporate Reporting Towards Sustainability - Towards an assessment method for comprehensive and universal sustainability reporting

Supervisors

in Portugal: Eduardo Oliveira Fernandes (FEUP); Isabel Soares (FEP)

Research progress and major scientific contributions

Measuring social corporate performance is a current challenge for companies and academia. Monitoring the evolution of the sustainability performance of each company is still hampered by the use of a very broad set of indicators, most of them with a qualitative character, hardly used for benchmarking activities. In some cases, selected indicators are not quite adjusted to the company core operations or to the specific challenges of the business sector. That raises the following questions: What must constitute the core of the sustainability corporate reporting? What must be identified as critical to be measured and reported in a commonly understood language? How to develop and assess a method that allows for transparency, accountability and benchmarking?

The main contribution of this work is the identification of a relevant set of Sustainability Key Performance Indicators (SKPI's) for the European energy sector. It is also expected to provide better understanding on the relation between corporate sustainability and financial markets. Electric Utilities, by their own nature and scope, are intended to be accountable to various stakeholders, while dealing with challenges emerging on a global scale.

The hypothesis that market tends to recognize the corporate sustainable behavior is core of this thesis. Employees, consumers and society value a company with social and environmental concerns, increasing its ability to survive in the long run. On the other hand, companies with no environmental or social concerns incur in direct or indirect losses regarding reliability and image, which usually, lead to loss of value. Presently, the valuation of a company in financial markets increasingly reflects not only shareholders expectations, but also other stakeholder's appreciation. Market recognition is used in this research as a "proxy" of general stakeholders recognition. To evaluate the market recognition of corporate sustainable behavior, we use volatility of corporate shares. It is expected that companies having more concerns about sustainability would present lower volatility on their stock prices. The methods used in this research include statistical techniques and econometric models to identify the correlation between indicators and perform the analysis of volatility. Econometric models are also applied to study the relation between SKPI from a sample of energy companies and their performance on financial markets. The preliminary results achieved indicate a correlation between sustainability reporting practices and the position of energy companies in the market, allowing the identification of explanatory factors.

Nuno Pereira	Portugal	SES	IST
Starting year	Estimate date of completion	Year	of
2007	11/2011	PhD	Amount of time spent at MIT
		4 th	12 months

Title of the thesis

Energy-Efficient Retrofit of Buildings in Lisbon (study about 1960's - 1970's typologies)

Supervisors

in Portugal: Luísa Caldas (FA-UTL), Manuel Correia Guedes (IST)
 at MIT: Leon Glicksman (MIT)

Research description and major scientific contributions

The objective of the research is to develop a methodology for a global building stock analysis in order to, in the end, define the best available retrofit options by building type for the adopted case study of Lisbon. The analysis began (during 2009/2010 period) by the Pombalino typology one of the more antique and standardized typologies, built before 1919. This study represented a test bed for the case-study typology (60-70's), which is now under progress.

The first task towards achieving the proposed goals was the categorization of the existing building stock, according to building type, age of construction, and typical construction methods used, based on the information of a sample of 200 buildings. The next step was the thermal modeling using Energy Plus (through Design Builder) simulating both a virtual and an existent building of each typology.

As a main task of the research comes the validation of these models through the results of a detailed 1 year field monitoring of 6 existing buildings (parameters: comfort, energy, occupation, air infiltration). A step of the most importance to give an added accuracy to the reference model inputs in order to have a solid base to work on the potential impact of energy-efficient retrofit measures. As a current task different energy-retrofitting measures are being simulated using the models, and prioritized in terms of return-on-investment periods. For the Pombalino test-bed study (developed during early 2010), the retrofit measures contributed to a thermal energy reduction of 49.2%. And in the free-float mode, to a better comfort of the occupants, equivalent to less 780 discomfort hours per year (24% less).

The final objective is to assess the potential for energy reductions at the urban level, by an optimal package of measures chosen for the specific chosen building type (1960-70's); and to develop a methodology to implement the outputs of the research in large-scale rehabilitation schemes, which is very likely to be happening in a near future, following an integrated and comprehensive analysis for the different stake-holders.

The main contribution of this research is the methodology development for analysis of city and countries building stock, using the more accurate figures and validating the thermal simulation models results with monitoring data from the field. This validation will allow more accurate results and a more informed decision-making concerning options for buildings energy retrofit.

Pedro Almeida	Portugal	SES	FEUP
Starting year 2007	Estimated date of Completion September 2011	Year of PhD 4 th	Amount of time spent at MIT 2 weeks

Title of the thesis

Impact of Vehicle to Grid in the Power System Dynamic Behaviour

Supervisor

João Abel Peças Lopes (FEUP)

References of the three best publications on your PhD research

J. A. Peças Lopes, F. J. Soares, **P. M. Rocha Almeida**, “Integration of Electric Vehicles in the Electric Power System”, Proceedings of the IEEE, vol. 99, no. 1, pp. 168–183, Jan. 2011.

Research progress and major scientific contributions

The purpose of this thesis is to identify grid operational management and control strategies that should be available with the presence of vehicles with plug-in capabilities. There is a high potential for Electric Vehicles (EV) to participate in several power systems services. This thesis focuses on the possible effects and benefits of EV connections on the systems dynamic behaviour, regarding in particular the participation in frequency control related ancillary services provision. Therefore, two research paths are pursued: primary frequency control and secondary frequency control.

In order to enable the provision of these controls a conceptual framework for EV integration into electric power systems was developed. Within this framework a market structure was proposed, where individual EVs are provided with market visibility by an aggregation unit, the Aggregator. For secondary reserves provision, after market closure the Aggregator receives set-points from the Automatic Generation Control (AGC) unit and distributes them among the EV it manages. For primary control, each EV must react locally to frequency deviations due to the need for fast action procedures (below 15 seconds) and send to the Aggregator a record of their activity for posterior remuneration for their service.

Using the proposed framework, two case studies were developed: one for primary frequency control in an isolated system and other for AGC operation in an interconnected grid.

In the first case study, a sudden drop in the wind speed was simulated, which led to the reduction of the active power production of the existing wind generators. Being a weak grid, such event leads to a large frequency deviation. However, when EV react to frequency changes the system is able to keep frequency closer to the reference value. The evolution of frequency was evaluated when the isolated system is subjected to the described event, with and without EV participation in frequency control. It was verified that EV only need to temporarily reduce their consumption value to improve the performance of the system.

In the second case study, a two-area system was studied and a load increase in area 1 was imposed. The evolution of frequency and the interconnection power flow were evaluated for the studied period. When EVs participate in AGC operation, frequency and tie lines power flow are restored much quicker and smoother way.

Pedro Fazenda	Portugal	SES	IST
Starting year 2009	Estimated date of completion 2013	Year of PhD 2 nd	Amount of time spent at MIT 2 months
Title of the thesis			
<i>Energy Efficiency Monitoring and Management to Promote Sustainable Behaviors</i>			

Supervisors

in Portugal: Pedro Manuel Urbano de Almeida Lima (ISR/IST)
at MIT: Una-May O' Reilly (CSAIL/MIT)

Research progress and major scientific contributions

Buildings are responsible for a considerable amount of the global energy bill. In Portugal, for example, they use 30% of the final energy, 35% of the primary energy and 60% of the electricity. Building resources should be carefully managed to achieve high efficiency and minimum waste, while still promoting a comfortable environment and social satisfaction with the working and living spaces. Over the past few years many articles have been published on the subject of Smart/Intelligent Buildings (SBs). The definition of intelligence, as defined in the artificial intelligence community, can be viewed as a property of a system that thinks like humans; thinks rationally; acts like humans or acts rationally, depending on the focus of the definition and how it is measured. In SBs, the term assumes a functional approach and is normally associated with the integration and automation of systems and functions to operate in ways that provide a responsive, effective and supportive environment, within which organizations can meet their performance objectives. SB can integrate the many systems that are part of the building and will act towards minimizing energy misuse and operating costs by manipulating available parameters, within an optimization space compliant with the comfort of the users of the building. The SB can monitor values of energy use and other parameters associated to user comfort, such as temperature, indoor air quality and lighting, and try to discover patterns and habits that may be associated to energy waste. With this information, users can be informed of the actual power consumption values, and be made more aware through feedback notification of their good behaviors, with impacts in the promotion of sustainable habits.

The focus of the PhD thesis includes aspects of knowledge representation for the domain of intelligent energy systems, using description logics, and machine learning with planning under uncertainty. Following the literature review, some of the work that was executed this year included the use of a Markov Decision Processes to control the heating, ventilation and air conditioning (HVAC) system in a way that adapts to the behavior of the tenants, while maintaining operation needs to a minimum. The idea is to reduce the HVAC system operation when the building or space is unoccupied and dynamically explore the heating and cooling set-points that satisfy user comfort, while minimizing the needs for thermal energy. The concepts of reinforcement learning, MDPs and Q-learning agents were studied and applied. A simple toy problem for room temperature control was formulated and a Q-learning agent was used to solve it. Future work will include extending the idea to the entire building while including other variables like e.g., lighting. This can include the creation of new algorithms to accomplish the proposed objectives while dealing with the complexity of the domain, partial observable environments and limited actuation capabilities.

Reza Fazeli	Iran	SES	FEUP
Starting year Sep 2008	Estimated date of Completion July 2012	Year of PhD 3	Amount of time spent at MIT 6 months so far (9 months expected)

Title of the thesis

Development of a multi-criteria evaluation framework for alternative light-duty vehicle technologies

Supervisors

in Portugal: Vitor Leal, Jorge Pinho Sousa
at MIT: Stephen Connors, Christopher Zegras

Main Publication

R. Fazeli, V. Leal and J.P. Sousa, A multi-criteria evaluation framework for alternative light-duty vehicles technologies, International Journal of Multi Criteria Decision Making, Accepted (in Press), 2011.

R. Fazeli, V. Leal and J.P. Sousa, "Development of a multi-criteria evaluation framework for alternative light-duty vehicles technologies", International Conference on Energy, Environment and Health – Optimisation of Future Energy Systems, Carlsberg Academy, Copenhagen, Denmark, May 31-June 2, 2010.

Research progress and major scientific contributions

This work could be divided into three main phases. In the first phase entitled "Flash Forward", the effort is dedicated to find the best alternatives for mid-term transportation planning. This phase includes several steps:

- Identification of main alternative fuel technology combinations applicable for light-duty vehicles (LDVs), through literature review,
- Comprehensive attributes characterization of the different alternative fuel technology vehicles for current and for (expected) future stages,
- Development of a Multi Criteria Analysis model to evaluate the alternative fuel technology vehicle fleet and applying a sequential Screening methodology in order to reduce a large set of alternatives to a smaller set that most likely contains the best choice.
- Application of the methodology to three different geographical contexts (e.g. Portugal, UK and Iran), in order to assess the most adequate technology for each context.

Currently, the first phase is finished and the results achieved from the developed model are being analyzed. An integrated scenario analysis to evaluate the impact of several factors is being followed.

In the second phase, our approach is to focus on the transition period for adoption of favorite alternatives resulted from first phase. System Dynamic will be applied in order to tackle the transitional issues including consumer acceptance, and relation between infrastructure development and sustained adoption of alternative fuel vehicles.

On final phase, the target is to try to incorporate the transitional issues into the multi-criteria decision making procedure. The plan is to evaluate the impact of different decision maker's attitude on the final results and assess the resilience of the results.

Sérgio Casimiro	Portugal	SES	IST
Starting year	Estimated date of	Year of PhD	Amount of time spent at MIT
2008	Completion	3 rd	12 months
	2012		

Title of the thesis

Optimization of CSP + D power plants in isolated areas, and potential business models

Supervisors

in Portugal: Christos Ioakimidis (IST), João Farinha Mendes (LNEG)
 at MIT: Steve Connors

References of the three best publications you have made on your PhD research

Under preparation.

Research progress and major scientific contributions

The work plan is defined now, together with all the institutions that are going to be involved. Our interests with this thesis are two. Firstly: obtain a tool that can give an idea of the feasibility of Concentrated Solar Thermal Power plants (CSP) coupled with desalination, as many of the areas in the world where CSP has the biggest advantage are in areas where the lack of water is an important issue. Secondly: Understand the optimum point between electricity and water production of such a power plant in a case scenario (a Mediterranean Island for example), and if possible understand business models that can be applied to deploy this technology in similar locations. Electricity prices are different throughout the day, week and period of the year, and as water production can be stored with relatively ease, it is important to study the possibility of such a production mix, and related costs to the energy system to which they may be connected. A tool called the Solar Advisor Model (SAM) was created by the US National Renewable Energy Laboratory (NREL), that is capable of analyzing the feasibility of CSP power plants for electricity generation. We are interested on creating an add-on to their model. The aim is that the updated version of SAM can analyze the costs of installing and running a CSP power plant with desalination capacity in a determined location defined by the user. As the SAM is based mostly in TRNSYS (a tool that simulates transient performance of thermal energy systems) for its technical assessment, it is proposed to create a deck in this model to simulate the operation of the desalination plant, so that it can work with the other blocks created in SAM for the analysis of the CSP plants for electrical production. A second stage will consist on the update of the technical economical model of SAM to have into account the water production of the combined plants (CSP+D). The second part of the PhD will consist on using a case study, preferentially of an isolated energy system in a location where water may also be scarce, to evaluate the optimum solution for the usage of such type of CSP+D power plants, and potential business models. The results obtained from analyzing the usage of CSP plants for electricity production in Portugal indicate that in scenarios with low CO₂ prices CSP will have a low expression in the electrical production. Only if CO₂ prices reach between 40 and 50 €/tone then CSP becomes the main option for electrical production.

Vasco Granadeiro	Portugal	SES	IST
Starting year 2008	Estimated date of Completion 08/2012	Year of PhD 3 rd	Amount of time spent at MIT 12 months
Title of the thesis <i>Optimization of Building Shape and Materials for Low Energy Consumption (provisional)</i>			

Supervisors

in Portugal: José Pinto Duarte (FA-UTL), João Ramôa Correia (IST), Vítor Leal (FEUP)
at MIT: William J. Mitchell (deceased, June 2010)

Research progress and major scientific contributions

Typically, architects and engineers see building design in different perspectives. To conceive a shape for a building, an architect will mostly consider aesthetics and architectural context, and will not be so meticulous with energy efficiency, the engineer's only concern. If the architect and the engineer could develop their own shapes for a certain building, the first would present a beautiful shape but probably inefficient and the second would present a simple shape, probably a box, very efficient but not aesthetically appealing.

The shape is the main variable to be defined in the early design stages and it is decisive for the energy behavior of the building throughout its lifetime. In the typical work process, the architect defines the shape, therefore his shape is the starting point. This research suggests a methodology to increase the energy efficiency of the starting shape, changing it through optimization, but within the architect intentions for the shape, within his flexibility for it. This way, the building shape will satisfy both the interests of the architect and the engineer. The selected method to embody flexibility was the design of rules to generate shapes (instead of the design of one shape), using the Shape Grammars formalism. The variables in these rules allow the generation of a great variety of shapes, and these are the variables to be optimized. The objective is to optimize the shape for a certain location and after optimize the shape and the materials together, since the latter exert a large influence on the energy performance.

An existing set of design rules (called a grammar) was selected as a case study to develop the methodology – the grammar of Frank Lloyd Wright's Prairie Houses – and programmed into Matlab, involving up to 60 variables. Matlab was linked to Energy Plus to automatically run an energy simulation to any generated shape to know its energy consumption (e.g. for the Lisbon climate). Next step is choosing an optimization algorithm to optimize the variables, being the energy consumption the objective function. Literature points to evolutionary algorithms as the best options, such as genetic algorithms or particle swarm optimization algorithms. After, materials, which are now constants, are going to be variables to optimize along with shape. Once the selection of materials enters the problem, makes sense to look at energy consumption from a life cycle perspective, which will be a new objective function.

2.4. Transportation Systems

2.4.1. Overview

The Doctoral Program in Transport Systems (DPTS) is a joint organization of the University of Coimbra, the University of Porto, and the Technical University of Lisbon. The schools directly involved in the program are IST, FEUP, and FCTUC, that is, the engineering schools of the three universities.

The DPTS was offered for the first time in the academic year of 2010-2011, to replace the separate doctoral programs in transport previously offered by the three universities, after being approved by the recently established Agency for the Accreditation and Assessment of Higher Education (A3ES). It is, to the best of our knowledge, the first doctoral program ever approved by this agency, with the decision being justified as follows: “It's a well-organized program, engages the three top Portuguese institutions in the area of transport systems, most of the more qualified professors and researchers, has the support of important research centers, establishes a healthy integration of facilities of the three schools, has clear, well identified, objectives and fulfills an area which is short of 3rd degree technical staff that can't be easily obtained in other countries”.

The goal of the DPTS is to prepare students to become leading actors in the transport world by:

- Providing a solid scientific education covering both the methodological approaches and institutional factors required to understand the transportation enterprise as an intermodal integrated system;
- Conducting cutting-edge research for the development of a world-class transportation system for passengers and freight in Portugal; and
- Working with industrial, government, and laboratory collaborators to provide added value to the program through research collaboration and teaching involvement.

Areas

The DPTS covers all transport systems topics, from transport policy and planning to infrastructure design and maintenance, at the various spatial levels (from international to local), and for the various modes (air, rail, road, etc.).

Up to now, the main focus areas have been:

- Air transport systems;
- High speed rail systems;
- Land-use/transport systems;
- Innovative urban transport modes/services;
- Intelligent transport systems; and
- Traveler information systems.

Of the 68 students currently involved in the DPTS (or separate predecessor programs in the three participating schools), 33 have an FCT-MIT Portugal scholarship, 19 of whom have already presented their “Thesis Project” successfully, and 7 have already spent a significant amount of time at MIT.

The theses of these 7 students illustrate the wide variety of subjects and approaches currently being pursued within the DPTS.

Two of the theses address air transport topics: congestion at airports and equity in air transport. One fits into the AirNets project, whose objective is to develop analytical tools to assist aviation authorities and air carriers to cope better with airport congestion, one of the major problems faced by the air transport industry. The other one deals with an important issue raised by the liberalization of air transport, because this leads air carriers to abandon non-profitable routes.

The area of high-speed rail is also represented with two theses. One of them is being carried out within the framework of the HSR-Life project. Specifically, it aims at assessing the feasibility of combining passenger and freight service in a HSR line, using Lisbon-Madrid as a case study. Within the other thesis, which is part of the HSR-Risk project, a methodology for line planning capable of coping with geotechnical, seismic and hydrological risks are being developed.

Intelligent transport systems is the research area of one of the thesis. Its main objective is to assess the safety benefits of Variable Speed Limits (VSL) in urban motorways and, based on the results obtained, provide recommendations on the best strategies for their application.

The remaining two theses can be seen as a contribution to the overall goal of the DPTS of training researchers and professionals capable of addressing transport problems – particularly in urban/metropolitan areas – from a system-level perspective. One of the theses, included in the SOTUR project, is analyzing how institutional design and decision-making mechanisms affect the overall performance of a transport system. The other looks at the implications of an ageing society with respect to travel demand, thus providing important information to take into account when designing transport services for the future.

Coordinators of Transportation Systems

António Pais Antunes, Faculty of Sciences and Technology, Univ. of Coimbra (PhD director)

Luís Picado Santos, IST, Technical University of Lisbon

Jorge Pinho de Sousa, FEUP, University of Porto

José Viegas, IST, Technical University of Lisbon

Richard Neufville, Engineering Systems Division, MIT (PhD director)

Chris Zegras, Urban Studies & Planning, MIT

2.4.2. Structure

The DPTS has a total (expected) duration of 3 years. In the 1st year, students make a doctoral course of 60 ECTS. This course comprises two mandatory (“M”) curricular units – “Research Methodologies” (6 ECTS) and “Thesis Project in Transport Systems” (30 ECTS) – and four optional (“O”) curricular units. At least two of the optional units must be chosen among the ones listed in the next table. The remaining ones can be chosen among any other doctoral units offered in the participating schools or in any schools with which they have doctoral collaboration agreements. The 2nd and 3rd years of the DPTS are dedicated to the preparation of a doctoral thesis of 120 ECTS. The curricular units listed in the following table are typically taught by faculty of two participating schools. Lectures are given in the school where the professor usually teaches, and broadcast to the other schools by videoconference.

The activity of a student of the DPTS takes place as follows. When the student is admitted, the director of the program in the respective host school, having heard the interests of the student, designates a tutor amongst the faculty involved in the DPTS or any other faculty member of the school approved by the Scientific Committee. The tutor helps the student to design her/his course plan and to become acquainted with all the research areas ongoing in the participating schools, other Portuguese schools, and in the international scene. This aims at helping the student to identify until May of the 1st year a suitable research area and a supervisor (or supervisors) for her/his future doctoral thesis, according to her/his research interests. The course plan and the supervisor of each student have to be approved by the Scientific Committee. With the support of her/his supervisor(s), the student must submit a thesis project specifying a research subject and a work plan by the end of the 1st year. The student must make a presentation and discuss the thesis project before a jury designated by the Scientific Council of the host school. Once the thesis project is approved, the student can start the preparation of the doctoral thesis. An Accompanying Committee including the supervisor(s), one element of the Scientific Committee, and one representative of a participating school, other than the host school will meet at least once a year to assess the progress accomplished by the student.

Structure of the doctoral program in Transportation Systems

Course	ECTS	Mandatory/Optional	Semester
Road Traffic Management	6	Optional	1st
Research Methodologies	6	Mandatory	1st
Transport Demand Modelling	6	Optional	1st
Transport Infrastructure and Operations Optimization	6	Optional	1st
Risk and Decision-Making	6	Optional	1st
Highway and Airport Infrastructure Engineering	6	Optional	2nd
Business Models and Contracts	6	Optional	2nd
Transport Policies and Institutions	6	Optional	2nd
Railway infrastructure design and maintenance	6	Optional	2nd
Simulation of Land-Use/Transport Systems Simulation	6	Optional	2nd
Thesis Project	30	Mandatory	Annual

2.4.3. New courses and faculty involved

For the Doctoral Program in Transportation Systems 6 new courses have been specially designed. These courses are taught by 21 faculty members from the Portuguese participant schools. MIT faculty participation is currently being defined as the new structure of this program was only put in place this academic year (2010/11).

2.4.4. Use of open-source community-based tools for learning

The transportation systems coordination is creating this year a platform on Moodle.

2.4.5. Benchmarking

In this section, we give information on the nine doctoral programs in transport against which we chose to benchmark the doctoral program in Transportation Systems. These are top-quality programs offered by well-known research universities. We include five programs from four European countries, two of which of a size similar to Portugal (The Netherlands and Denmark), and four from North America.

Location: Departamento de Infraestructura del Transporte y del Territorio, Departamento de Ingeniería Mecánica, and Departamento de Organización de Empresas.

Structure

- Teaching stage: 60 ECTS included in one or several Master courses, preferably those associated with the doctoral program.
- Research stage: Defense of a thesis proposal, and preparation and defense of doctoral thesis. Teaching stage should be finished before the research stage is initiated.

Areas

- Planning and design of transport infrastructure networks
- Mathematical analysis and numeric modeling of transport systems and their territorial impacts
- Organization and operations of transport and logistics systems
- Analysis of the connections between spatial development and transport networks
- Economics, financing, and assessment of transport infrastructure construction and exploitation.

Admission requirements: Diploma in Engineering – mainly Civil (“Camino”) and Industrial – or similar (Architecture, Economics, etc.).

PhD in Transport – Imperial College

Location: Centre for Transport Studies, Department of Civil and Environmental Engineering

Structure: Non specified

Areas

- Travel behavior and transport modeling
- Transport technology and telematics
- Transport operations
- Transport and environment
- Transport policy and regulation
- Railway operations and management
- Geomatics
- Port operations and logistics
- Air transport operations and planning
- Freight transport and logistics
- Safety

Admission requirements: Applicants for a research degree (MPhil/PhD) should have or expect to obtain a first or upper second-class honors degree or equivalent, in a relevant quantitative discipline (e.g., Engineering, the Physical Sciences, Environmental Science, Mathematics/Statistics, Computing, Economics). A Master's degree (not necessarily in transport) may be advantageous, but is not essential.

PhD in Transport – University of Leeds

Location: Institute for Transport Studies, Faculty of

Areas

- Transport and energy
- Understanding travel behavior/choices
- Freight: Mode choice in freight transport
- Air/high speed rail
- Transport policy and the low carbon society
- Modeling network interactions
- Transport and environment
- Human factors and highly automated driving
- Impairment and driving performance

Structure

The timeline and milestones of a “typical full-time route to successful completion of a PhD” is outlined in Fig. 2.

Month	Tasks	Outputs
1-3	Induction Discuss and agree the Training Plan Initial training course - 'Starting your PhD' Core reading	Personal Training Plan
4-6	Literature review Define objectives Prepare for mock upgrade Attend UTSG conference Compete mock upgrade	Short literature review Mock upgrade note
7-9	Develop methodology Prepare upgrade report	Draft upgrade report
9/10	Upgrade examination	PhD upgrade report
12	Deadline for upgrade	Revised Plan
Year 2		
13-15	Core research	
16-18	Core research Prepare conference paper	Conference paper (e.g UTSG)
19-21	Core research and draft chapters	
22-24	Submit end of Year 2 paper and Plan	Year 2 paper and Plan
Year 3		
25-27	Apply Plan – develop journal paper (e.g convert conference paper)	
28-30	Complete core research Present at a national or international conference	Conference/journal paper
31-33	Submission of chapters to supervisors	
34-36	Review draft thesis Write-up and submit thesis	PhD thesis

(Note - different timescales /milestones apply to MPhil and part-time PhDs.)

Fig. 2: Timeline and milestones of a PhD in Transport at the University of Leeds.

These two milestones are of particular importance:

- Assessment of the first year: Students seeking a PhD are initially registered with 'provisional' status. At the end of the first year progress is reviewed and the registration status changed, subject to a successful upgrade. This upgrade is an assessment of performance, and takes the form of a written report and oral presentation to a panel. The primary aim of this and other processes is to help keep the student on-track for successful completion.
- Feedback at the end of the second year: Towards the end of the second year students submit a paper about their progress, which is considered by both supervisors and their Postgraduate Tutor. This includes an updated plan to detail the student's path to submission, for approval prior to registering for year three.

Admission requirements: Applicants for a research degree should have or expect to obtain a first or upper second-class honors degree or equivalent, preferably in a quantitative discipline. A Master's degree (not necessarily in transport) may be advantageous, but is not essential. Candidates should have a clearly specified and achievable research goal.

PhD in Transport – Delft University of Technology, Erasmus University Rotterdam, Radboud University Nijmegen, University of Twente, and University of Groningen

Location: TRAIL Netherlands Research School on Transport, Infrastructure and Logistics (“TRAIL is a collaborative initiative of five Dutch universities, and has been accredited as research school since 1997”).

Structure

The activity of a student is established according to personalized Ph.D. agreements specifying an education and training plan, a research plan, a publication plan, and an agreement on support and supervision.

The education and training plan includes general introduction courses on the interdisciplinary TRAIL fields of interest, courses to overcome possible initial deficiencies in knowledge or skills of Ph.D. candidates, and in-depth courses on skills and scientific topics in the specific scientific area to which the Ph.D. program contributes

The Ph.D. agreement is made up within the first half year of the TRAIL membership of a new Ph.D. by the student together with his supervisor and promoter and approved by the scientific director of TRAIL. The arrangements are monitored on annual basis and can be revised if necessary. The arrangements and procedure can be tuned to the criteria of and be included in the regular, (annual) personnel evaluations as performed by the participating faculties in TRAIL.

The whole of the Ph.D. agreement and the course program are based upon the required final attainment level of students and are tuned to strengthen the career perspectives of alumni.

Areas

- Mobility
- Transport

- Logistics
- Traffic
- Infrastructure
- Transport systems

Admission requirements: NA

PhD Studies in Transport – Technical University of Denmark

Location: Department of Transports of TUD

Structure

- 1st semester: 30 ECTS of courses (at least 20 made from dedicated PhD courses)
- 2nd to 6th semester: PhD research, complemented with teaching (3 months), project work on a relevant field (6 months), and visit to foreign university.
- The student is expected to publish “3-5 international papers (preferably in journals) during the study”.

Areas

- Traffic safety
- Decision modeling
- Transport economics
- Transport models (ModelCenter)
- Traffic modeling
- Logistics and intelligent transport systems

Admission requirements: Master’s degree completed with B (ECTS scale), 76 (percent), or 8.4 (Danish 7-step scale).

Interdepartmental Doctoral Program in Transportation – MIT

Location: Department of Civil and Environmental Engineering (administration)

Areas: Non specified

Structure

- The program requires the completion of at least 150 units of a Program of Study by the student, the successful completion of a General Examination, which consists of both written and oral components, and the submission and defense of an acceptable dissertation.
- The Program of Study consists of:
 - The Doctoral Core Program: At least six subjects totaling at least 66 units that represent the student’s area of specialization. The six subjects must include at least two “methodological” subjects and two “transportation” subjects. The core defines the student’s area of in-depth knowledge.
 - The Remainder: A set of subjects in transportation and related fields. As part of the remainder, a breadth area consisting of three subjects (at least 27 units) defining a knowledge base in a field distinct from the student’s core program,

but complementary to that focus. The relevance of this breadth area to the student's transportation interests must be explained as part of the student's program proposal. The remainder of the program may include up to 45 units of graduate level subjects taken elsewhere.

- The General Examination is expected to be taken no later than the fourth semester of graduate study. The written exam is administered first, followed in about two weeks by the oral exam. The written exam is a take home, open book examination. It consists of four separate questions administered over four consecutive days. On Day One all students will be given a common question covering core subjects. On Days Two, Three and Four, students can choose two out of three questions from the following areas: Transportation Demand and Economics; Transportation Supply and Operations; and Transportation Planning and Policy. The oral exam consists of the presentation and discussion of a research paper (possibly based on student's master's thesis) of up to seven pages submitted prior to the beginning of the written exam. Although questions usually focus on the student's oral presentation, specific questions related to the student's doctoral core program and the student's response on the written exam may be asked.

Admission requirements: Students currently registered in an MIT master's degree program, as well as students with or working toward a research-based masters degrees (i.e., with a research thesis) from other schools.

PhD Program in Transportation Engineering – University of Maryland

Location: Department of Civil and Environmental Engineering (administration)

Areas

- Transportation planning and policy
- Traffic operations and control
- Travel demand analysis
- Transportation operations research
- Public transportation systems
- Air transportation systems
- Freight transportation and logistics

Structure

- Completion of eight courses beyond the student's MS program requirements. These courses must be determined by the student in consultation with and subject to the approval of the student's supervisor.
- Successful completion of a PhD Qualifying Examination. This exam is administered in three parts: (1) a one-day written examination covering transportation systems engineering fundamentals and methodological basics; (2) a two-day written examination covering the student's areas of specialization in Transportation; and (3) an oral examination.
- Successful defence of a research proposal. After the qualifying exam is passed, the student will form a PhD dissertation committee in consultation with his/her research supervisor. This committee must consist of a minimum of 5 graduate faculty members, including at least one "external" member who will serve as the Dean's Representative. The "external"

member must be from the University of Maryland at College Park but not from the Engineering School. A dissertation research proposal must be prepared, presented to, and approved by this committee.

Admission requirements: Applicants must have a minimum GPA of 3.5 to apply to the Doctoral Program and a GRE with scores of at least 650 in the quantitative and analytical parts. Applicants with lower GPA's and/or GRE may be considered and accepted in a provisional basis if other indicators of ability are exceptional (letters of recommendation, prior experience ...).

PhD Program in Transportation Technology and Policy – University of California Davis

Location: Institute of Transportation Studies

Areas

- Technology track: systems-level planning, analysis, management, and design of advanced transportation technologies (especially vehicle propulsion and “intelligent transportation systems”).
- Policy track: public policy and planning issues related to transportation, especially the social and environmental impacts.

Structure

- The PhD degree will require completion of course requirements and a dissertation. The normative time for a PhD is 4 years.
- Students must complete 54 total units (including units completed toward a relevant MS) from 7 core courses, as well as at least three additional technology or policy courses in the chosen track and one additional course in the alternate track. At least 2/3 of all credits must be at the graduate level. The core courses are in the following areas: Transportation Technology, Transportation Policy, Transportation Systems, Research Design, Economics, and Transportation Models and Quantitative Methods (2).
- First-year students must make the Transportation Orientation seminar and the Leadership, Professionalism, and Ethics seminar.
- Students must make the ITS seminar every quarter for 2 years and some number of research units every quarter for the entire program.
- Students must pass the PhD Qualifying Examination.

Admission requirements: Students normally will have earned a minimum grade point average of 3.5 and must also submit GRE scores and three letters of recommendation. International students are expected to achieve a minimum score of 550 on the paper-based and 80 on the iBT Test of English as a Foreign Language (TOEFL).

PhD Program in Transport and Logistics – University of British Columbia

Location: Centre for Transportation Studies, Sauder School of Business

Areas: The program is a cross field within Business Administration, or (and) interdisciplinary across the University. Although the program is designed to meet the needs of individual students, there are two main streams: one focusing on transport economics and policy analysis, and another focusing on logistics and supply chain management.

Structure

A typical schedule for a PhD student in the program might be:

- Year 1 Fall - COMM 693 (Research Methods), and two or three electives
- Year 1 Winter - COMM 644 (advanced topics in transportation), and two or three electives
- Year 1 Summer - Summer research paper
- Year 2 Fall - Teaching Methods and two or three elective courses
- Year 2 Winter - three or four elective courses
- Year 2 Summer - Comprehensive exam
- Years 3 and 4 - Preparation of presentation of thesis proposal and preparation and defense of thesis.

A list of about 20 elective courses is available for both the Transport Economics and Policy Analysis Stream and the Logistics and the Supply Chain Management Stream.

Admission requirements: “Students applying for our PhD program are expected to have a good master’s level training in quantitative methods. Those who do not have such a training are encouraged to apply to our Masters of Science (MSc) program in Transportation and Logistics before going on to a PhD. Students who qualify for an admission into the PhD program but do not have adequate backgrounds in some areas may be required to take some prerequisite courses”.

Conclusion

Over the 4-5 years of the post-graduate education network, it was possible to set up a Doctoral Program in Transport Systems (DPTS) offered jointly by the three Portuguese engineering schools with the strongest transport research groups. The program is attracting on average 15 students per year, an amount that we believe is consistent with the available supervision capabilities and the country R&D needs.

The comparison of the program with world-leading doctoral programs in transport reveals similarities and differences. With respect to structure, the most different are perhaps the programs offered by the English schools (Imperial College and University of Leeds), especially because they do not involve a (significant) teaching component. The most similar are probably the programs offered in the smaller European countries – TRAIL in the Netherlands and the Technical University of Denmark – as they both involve a teaching component in the 1st year followed by a research component. In the case of TRAIL, not only the program is offered by a consortium of schools (including the Delft University of Technology and the Erasmus University Rotterdam), but also the size of the teaching component is exactly the same as in the DPTS (60 ECTS). In the North American universities (MIT, University of Maryland, University of California Davis, and University of British Columbia), the programs are more complex, because of a longer teaching period and the existence of a general examination. As regards the focus areas, the DPTS is certainly close to programs clearly based on engineering schools – such as the programs of the Polytechnic University of Catalonia, the Imperial College, the MIT, and the University of Maryland – but, in so far as we could understand, differences to the other programs are small. Also, no significant differences were noticed in relation to admission requirements – a Master’s degree (with a good mark) is in principle necessary, but the principle is not strictly applied.

The first steps towards a competitive doctoral program in transport systems based in Portugal were made, but there is still plenty of ground to cover before the ambitious goal it pursues can be fully met. In particular, it is necessary to make a thorough assessment of the program after the completion of the current edition – in close collaboration with MIT. The improvements this assessment will allow to make will be crucial to enhance the probability of success of the program.

2.4.6. PhD theses

This section shows the profiles of each student who has spent some period of time at MIT.

The home institution of each student is indicated on the first line as:

IST – Instituto Superior Técnico – Technical University of Lisbon

FCTUC – Faculty of Sciences and Technology - University of Coimbra

FEUP – Faculty of Engineering – University of Porto

Alda Metrass Mendes	Portugal	TR SYS	FEUP
Starting year 2007	Estimated date of Completion 12/2011	Year of PhD 4 th	Amount of time spent at MIT 18 months

Title of the thesis

Air transportation design for effective and efficient service to small remote communities: Policy options under regulatory reforms

Supervisors

in Portugal: Álvaro Costa (FEUP)
at MIT: Richard de Neufville

Main Publication

Metrass-Mendes, A., de Neufville, R. (2011), Air transportation policy for small communities: lessons from the U.S. experience (submitted for publication)

Research progress and major scientific contributions

The last decades have witnessed a global trend toward airline deregulation, with significant impacts on national provisions for air service of smaller communities. One of the consequences of liberalization is that the carriers are no longer constrained to serve routes, and may thus neglect service to less profitable destinations with lower density traffic. Deregulation can therefore have detrimental effects on small remote centers.

Though many governments agree on the obligation of preventing discontinuity of service to these communities, there is no common accord on how national air transportation policies should be designed to support this objective. While some nations have opted for full deregulation and to sustain the service through subsidies paid to carriers competing for contracts, others chose to maintain the status quo and others to carry on lighter forms of regulation in hybrid forms. Different national contexts also result in that a solution that is appropriate for one country may not be the most successful for another.

The working hypothesis is that the analysis of multiple worldwide experiments with air service of small remote communities will allow the identification of best practices. The main argument is that the policy design that works better in each case can be acknowledged, and thus provide a good starting point for further policy formulation and recommendations.

The research for the world best practices in policy design is developed from the evaluation of mature experiences of the U.S.A. government, Canada and the Northern Territories, and Australia, and the assessment of progress toward deregulation in countries like Portugal, Spain, and Brazil, according to two criteria: effectiveness and efficiency. The study will make recommendations for the design of air transportation policies for countries where deregulation and the provision of small communities are under discussion, derived from the reference cases.

Ana Costa	Portugal	TR SYS	FCTUC
Starting year 2008	Estimated date of Completion August/2012	Year of PhD 3 rd	Amount of time spent at MIT 12 months

Title of the thesis

Risk Assessment and Management for High-Speed Rail Systems based on Scenario Descriptions under Uncertainty

Supervisors

in Portugal: Maria Conceição Cunha (FCTUC) and Paulo Coelho (FCTUC)
at MIT: Herbert Einstein (Sponsor Professor at MIT)

Research progress and major scientific contributions

Planning of High-Speed Railways (HSR) must consider multiple and uncertain future conditions, including natural phenomena such as flooding, earthquakes, etc. Various alternatives can be adopted for corridors and technical solutions, which may yield considerably different overall performance. A survey was firstly conducted among experts from industry and academia to identify and characterize risk factors for high-speed rail lines in different ground conditions. The results reveal the need to address the problem and reflect both industry and academia's concerns regarding the issue. Useful answers were obtained for the quantification of the risks involved. A major achievement was the development of a framework of analysis, which represents a significant advance with respect to current approaches to the problem. A computational tool was subsequently coded to allow dealing with all the information needed. This user-friendly tool was developed in C# language linked to a powerful database, the Microsoft SQL Server 2008. It allows the consideration of search space properties through descriptive property layers, the HSR design specifications and costs, an optimization model and the implementation of the Simulated Annealing Algorithm (SAA) to solve the model. Applications to case studies of increasing complexity and magnitude have been performed in order to estimate the SAA parameter combination yielding the best results and to highlight the influence of problem specifics in the process. Results are currently being analyzed for the completion of a paper to be submitted to an international journal in the field of operations research. These applications of the tool and model report to a scenario of normal operational conditions. Future developments will include scenarios of extreme conditions and application of the tool to a real HSR case study. Connectivity with Geographic Information Systems is possible if the data is available in a proper format. On completion of the research, decision aid tools based on robust optimization techniques will be available considering scenarios with an importance degree to be specified by the decision maker. These will enable the consideration of geotechnical, seismic and hydrological risks for HSR in order to achieve solutions that performs well for the different scenarios considered, even if they do not represent the best solution for a particular scenario within the infrastructure's lifetime.

Carlos Lima Azevedo	Portugal	TR SYS	IST
Starting year 2008	Estimated date of completion 2012	Year of PhD 3	Amount of time spent at MIT 11 months
Title of the thesis <i>Safety criteria for the management of variable speed limits</i>			
Supervisors in Portugal: João Cardoso (LNEC); José Viegas (IST-UTL) at MIT: Moshe Ben-Akiva (CEE)			
Research progress and major scientific contributions The main objectives of this research thesis are: the integration of safety assessment models in the state-of-the art traffic micro-simulation tools by developing accident prediction models for the urban motorway environment; the identification of the safety benefits of Variable Speed Limits systems (VSL) in urban motorways and recommend best strategies for its application; and the study of the ITS effects on driver behaviour, and identify which of the related changes may influence road safety. Regarding the thesis tasks, the student has: undertaken a comprehensive review of existing APMs, driver behaviour models and application off VSL signs for network efficiency; collected part of the data needed for the case study; designed and calibrated a Portuguese urban motorway pilot site in the micro-simulation application MITSIMLab (developed at MIT); worked with the ITSLab (MIT) on the new developments of MITSIM driver behaviour models and core-structure; started a sensitivity analysis on the existing driver behaviour model parameters; and started the design of the APM that will be integrated with MITSIMLab. Besides the continuation of the case study simulation and the design of the APM, further tasks to be undertaken by the student are: modelling of the VSL system, definition of its control strategies and evaluation of their effectiveness in reducing accident risk; conclusions and recommendations of best strategies in the application of VSL systems in Portuguese urban motorway sites.			

Diana Silva Leal	Portugal	TR SYS	FCTUC
Starting year 2008	Estimated date of Completion August, 2012	Year of PhD 3 rd	Amount of time spent at MIT 6 months
Title of the thesis <i>Goods Traffic on High Speed Railway Line Lisbon-Madrid</i>			
Supervisor			

in Portugal: Luís Picado-Santos (IST)

Research progress and major scientific contributions

High Speed Rail (HSR) investments have been a subject of great interest for the Europe Union. Given that these require large public investment, once decided, it is important to think about how to use the system in the most efficient way. The motivation for the study leads to interest in the MIT of Multi-Attribute Tradespace Exploration (MATE) method and its applicability in the development process for several types of products and situations. The method has been show to enable better concept decision making in space system applications, however it has never been applied to the analysis of a transportation problem as in this implementation of a HSR project. The MATE method was selected with the propose of analyzing the trade-off between a certain number of criteria and to be able to understand the possible range of solutions and apply this methodology to deal with complex transportation problems as is the HSR line project. The main objective is to use MATE applied on the future Lisbon-Madrid HSR line. This methodology addresses the feasibility of the introduction of freight on the operation of the line admitting that the rolling stock will be of the same type of the passenger's rolling stock and that freight will use the open slots beyond passengers' service. This procedure integrates technical data from rail operators and also data provided by stakeholders with a strong interest in the evaluation of different strategic scenarios and helping in the decision making process about decisions on HSR line. Until now the work done was mainly related with data acquisition and data analysis from interviews done to the most important stakeholders involved. The strategic scenarios are being set-up in order to define the most appropriate framework regarding passengers and cargo decisions. It is expected that within the next months it will be possible to have an application of MATE treating the described HSR case and by this way making the validation of a powerful tool for the study of complex transportation problems that was not yet accomplished in this scientific field. The research is now part of the EXPRESS research project set up under the MIT PORTUGAL. The project mainly seeks the establishment of the overall socio-economic impact of that rail line.

João Pita	Portugal	TR SYS	FCTUC
Starting year 2008	Estimated date of Completion 07/2012	Year of PhD 3 rd	Amount of time spent at MIT 12 months
Title of the thesis Optimization of Air Traffic Network Design under Congestion			

Supervisors

in Portugal: António Pais Antunes (FCTUC)
at MIT: Amedeo Odoni, Cynthia Barnhart

References to the three best publications on PhD research

Pita, J., Barnhart, C., Antunes, A.. "Optimization model for integrated schedule design and fleet assignment models under congestion", submitted to Transportation Science.

Research progress and major scientific contributions

Air traffic flows have increased considerably over the years, as the world economy became more globalized and tourism became one of the main industries on the planet. One of the main implications of the air traffic increase is congestion at airports, which has tremendous impact on airlines and passengers. As different agents in the air transportation system, airlines and civil aviation authorities that protect the public interest have distinct goals. To cope with these problems two optimization models were developed aiming to assist both airlines and civil aviation authorities.

To assist airlines an integrated schedule design and fleet assignment model has been developed which takes aircraft and passenger delay costs explicitly into account. The objective is to maximize the expected profits of an airline that faces a given itinerary-based demand and operates in congested, slot-constrained airports. Both airline competition and airline cooperation are dealt with in the model in a simplified manner. The model was applied to a case study involving the main network of TAP Portugal (31 airports and 100 daily flight legs). The results suggest that profits can increase, while diminishing the total number of flights and increasing slightly the passengers' average connecting time. The computation effort involved in the application of the model is sufficiently small to allow its real-time utilization in IATA scheduling conferences.

Currently, a second optimization model is being developed to be applied to a busy, congested, and slot-constrained air transportation network with the objective of analyzing the impact of alternative slot allocation policies, including their effect on expected delay time at airports. First, we study the existing situation in terms of total costs of the system, passenger demand per flight-leg, slot distribution, and expected delay time and cost. Then we apply a cost minimization optimization model to evaluate possible improvements in the system by reducing or reorganizing the number of slots to reduce expected delay. This analysis takes into account the current market power of each airline, and the passenger demand per flight-leg. An application using data from the 34 busiest airports in Europe will be performed soon.

Maria Spandou	Greece	TR SYS	IST
Starting year 2009	Estimated date of Completion 2012	Year of PhD 3 rd	Amount of time spent at MIT 5 months (out of 12)

Title of the thesis

Institutional Design as Performance Factor in Urban Mobility Systems

Supervisors

in Portugal: Rosário Macário (IST)
at MIT: Joseph Sussman

Research progress and major scientific contributions

The main objectives of my PhD dissertation are the following: (i) obtain a sound knowledge base on the relation between institutional design theory and performance management, (ii) understand and assess the decision-making mechanisms in the transport policy, planning and operations level, as well as the interrelations and interactions among stakeholders, and the vertical consistency between levels of decision and (iii) identify and assess the influence and impact of institutional design parameters of Urban Mobility Systems on the individual and overall system performance. Methodologically, the main directions of my research can be summarized as comparative quantitative and qualitative analysis (multi-methodological approach), from a theoretical and empirical perspective.

Because of the great number of fields and disciplines involved in the problem that I am researching on, a large-scale literature review with references to transportation, institutional analysis, management, economics, public policy, political science, industrial organization, etc is considered essential and has been the main work progress so far. Of course this is an ongoing process. The opportunity of having access to the libraries' material and other databases at the MIT, as well as personal communications with MIT academics in various of these fields, have been very beneficial for this phase of my dissertation. Under the guidance of my supervisors I attended lectures that could assist my research and improve my knowledge and abilities in certain areas, such as Contract and Organizational Economics, System Dynamics, Negotiations, Presentation skills, Publications etc. Furthermore, my participation throughout the fall semester in the High Speed Rail/Regions and Managing Metropolitan Mobility Group meetings has also given me opportunities for discussion and exchange of ideas.

My contribution so far is the development of a comprehensive and interdisciplinary framework that would allow for systematic and well-grounded analysis of the research problem I am tackling, which in a future phase, complemented by the appropriate modeling and other scientific tools and data, would assist stakeholders that need to address organizational, financial/funding and performance issues, in order to achieve better efficiency, effectiveness and sustainable development of the Urban Mobility System.

Rafaela Arriaga	Portugal	TR SYS	IST
Starting year 2007	Estimated date of completion May 2013	Year of PhD 4 th	Amount of time spent at MIT 6 months
Title of the thesis <i>Transport Needs For an Ageing Society: long terms drivers and generational effect</i>			
Supervisors In Portugal: José M Viegas (IST) At MIT: Professor M Ben-Akiva			
Research progress and major scientific contributions Over the next 40 years the number of persons over 65 years-old will dramatically increase across Europe and form a new and different generations of older citizens in regard to their health, their wealth, their lifestyles and their travel needs. This thesis compares three generations of ageing persons and aims at understanding the transport needs incorporating the cohort effect. Drawing on the theories of cohorts, planned behaviour, life course perspective and utility theory, this study investigates empirically the existing generation differences in travel among three living generations. Primary data shall be obtained from a lifetime-retrospective survey and used to estimate the demand models. The models that explain 65+ mobility severely understate the mobility prediction without the cohort effect. Mobility needs of the next cohorts cannot be predicted with current models. <i>“There is widespread recognition that the emerging cohorts will be different from today’s older drivers, in regard to their individual health, their expectations as they age and especially, their travel demands. However cohort studies, arguably the most effective means of identifying and responding to emerging differences, are relatively rare and currently at least, make few appearances in the research literature. This is considered to be a serious limitation in our capacity to respond proactively to the challenges and benefits of an ageing society”</i> (Charlton 2006) This study can. Therefore, contribute to both filling the above gap and enlighten the forecast matter using primary data. At the Official Seminar of PhD Research Proposal, CAT (Nov 22nd, 2010), the project was on target with the plan, however two main issues were outstanding: a DCM course and the programming of the retrospective survey to php. Both issues are being solved with the kind help of my two supervisors.			

3. Master's of Business Engineering (MBE) and Master's of Science Programs (MsC)

3.1. Complex Infrastructure Transportation Systems MSc.

3.1.1. Structure

The students of the Master's of Science in Complex Transportation Systems need to complete 60 ECTS units that correspond to all the courses of the curricular plan presented in the table below. Those who obtain a classification equal or above 14 (on a 0-20 scale) on the curricular part can progress directly to the thesis and choose a supervisor with the support of the director of the program.

Structure of the Master's program in Complex Transportation Systems (CTIS)

Course	ECTS	Mandatory/optional	Semester
Risk and Decision Making	6	Mandatory	1st
Information and Communication Technology	6	Mandatory	1st
Transportation Systems Analysis	6	Mandatory	1st
Transport Economics and Project Evaluation	6	Mandatory	1st
Transport Planning and Performance Assessment	6	Mandatory	1st
Transport Policy and Institutions	6	Mandatory	2nd
Transport Technology and Operations Management	6	Mandatory	2nd
Project Management and Large Scale Integration	4.5	Mandatory	2nd
Business Models and Contracts	6	Mandatory	2nd
Structured Financing of Transport Projects	6	Mandatory	2nd
Thesis project	1.5	Mandatory	2nd
Thesis	30	Mandatory	3rd

Students will have to submit their thesis by the 31st of October of the following year after their admittance in the program to conclude within the 3 semesters of the course, but they can apply for a 7 months extension, effectively bringing their course to 2 years.

Coordinators of Transportation Systems

António Pais Antunes, Faculty of Sciences and Technology, Univ. of Coimbra

Luís Picado Santos, IST, Technical University of Lisbon (CTIS director)

Jorge Pinho de Sousa, FEUP, University of Porto

José Viegas, IST, Technical University of Lisbon

Richard Neufville, Engineering Systems Division, MIT

Chris Zegras, Urban Studies & Planning, MIT

3.1.2. New courses and faculty involved

For the CTIS Master's Program 10 new courses have been specially designed. These courses are taught by 18 faculty members from the Portuguese schools plus some other guest speakers from the corporate sector and by 6 faculty members from MIT. MIT faculty ensures 16% of the teaching (academic year 2010/11).

3.1.3. Use of open-source community-based tools for learning

The CTIS program uses the Stellar server, which is the MIT course management tool, where the syllabus, pre-readings, PowerPoint presentations, bibliography, and assignments for each of the courses are made available to students. The faculty uses this platform to interact with students and the students interact with each other and faculty through the same system.

3.1.4. Sponsors

There are 8 major international companies sponsoring scholarships for students attending the CTIS MSc. program: Alstom, Bento Pedroso / Odebrecht, BRISA, IMTT – Instituto da Mobilidade e Transportes Terrestres, Mota-Engil, RAVE, Refer and Siemens.

3.1.5. Benchmarking

In this section we present the benchmark of our Master's program in Complex Infrastructure Systems (CTIS) with a wide range of offers across Europe. Given the shorter duration of the Master's in comparison with the PhD programs, we took only prestigious European schools in the comparison set (Table below).

Because of the multiple agents and perspectives involved in Transport Systems, it quickly becomes evident that there are in fact several "families" of Masters Courses with a relevant Transport component. The CTIS Masters does not fit exactly in any of these families as it was designed from its inception, trying to cover the multiple perspectives needed for its alumni to be relevant players in the overall management of complex projects.

The main facts obtained from the benchmarking table are as follows:

1. A total of 28 Masters Courses from prestigious Universities, with significant Transport component has been surveyed, in 8 European countries. The countries with a higher number of courses offered are UK (15), The Netherlands (3) and Switzerland (3),
2. These courses can be grouped in 5 thematic areas, also with different numbers of offers: the most represented thematic area is Transport Planning and Modelling (13), followed by Transport Economics, Business and Management (5), and by Logistics and Supply Management (4),
3. There are offers with a duration of 2 semesters (18 courses, all themes except Transport Policy), and 4 semesters (11 courses, all areas except Transport Economics, Business and Management),
4. Regarding fees per year, the quartiles are as follows: First at 10k, second at 13k, third at 16720, fourth at 27500,
5. The average fee/year per Thematic group is: Logistics and Supply Chain Mgmt with 12785; Transport Economics, Business and Management with 15460; Transport Policy with 11250; Transport Planning and Modelling with 12860; Transport Technologies with 10280. In all thematic areas there is strong variation, particularly from the presence of a few offers with very low tuition fees,
6. A total of 5 courses have tuition fees below or around 1000 Euro, all in CH, Germany and France. No information was available for one course in Sweden (KTH) but we know that until recently it had a tuition fee of virtually zero.

From these facts, and comparing with the CTIS situation, we can obtain the main conclusions of the benchmark:

1. Regarding contents, the CTIS continues to have (as it had when it started) a unique formula covering the "virtuous triangle" of Engineering and Project Management / Finance and Contracts / Policy and Institutions, which we believe allows its graduates an advantageous position regarding jobs in complex settings.
 - a. This uniqueness could be taken as a weak point, but the overall reaction of candidates as well as of corporate sponsors, is very much in its favor. It is believed this should be pointed out even stronger in subsequent dissemination of the course;
2. On the duration, CTIS is the only one with 3 semesters, with all other courses divided at about 2/3 with 2 semesters plus 1/3 with 4 semesters. However, it must be pointed out that the Portuguese legislation does not allow awarding a Masters title in only 2 semesters.
3. Regarding tuition fees, if we consider only the courses with at least the levels of the non-integrated masters at IST (2500 Euro/year), the cost of CTIS places it at the 25th percentile, i.e. 3/4 of the competing courses are more expensive.

BENCHMARK OF THE MASTERS IN COMPLEX TRANSPORT INFRASTRUCTURE SYSTEMS AT IST (MIT-PORTUGAL PROGRAM) WITH OTHER EUROPEAN MASTERS COURSES WITH A STRONG TRANSPORT COMPONENT

FEBRUARY 2011 - Overview Table

Country	University	Theme	Degree	Duration (sem.)	Credits	Tuition Fee / year (Euro) [non-Eu student]
Denmark	DTU Technical University of Denmark	LSCM - Logistics and Supply Chain Mgmt	MSc Transports and Logistics	4	120	13500
France	Université Lille - Sciences et Technologies	LSCM - Logistics and Supply Chain Mgmt	Management Logistics and Transport Engineering	2	60	450
Sweden	Univ.Göteborg - School of Business, Economics and Law	LSCM - Logistics and Supply Chain Mgmt	MSc Logistics and Transportation Management	4	120	27192
United Kingdom	University of Westminster	LSCM - Logistics and Supply Chain Mgmt	MSc Logistics and Supply Chain Mgmt	2	60	10000
Belgium	Universiteit Antwerpen - ITMMA	TEBM - Transp. Econ., Business and Mgmt	MSc Transport and Maritime Management	2	60	12000
The Netherlands	VU Univ. Amst. - Faculty of Economics and Business Adm.	TEBM - Transp. Econ., Business and Mgmt	MSc Spatial, Transport & Environmental Economics	2	60	12000
United Kingdom	University of Leeds - Faculty of Environment	TEBM - Transp. Econ., Business and Mgmt	MA Transport Economics	2	60	14200
United Kingdom	Newcastle University	TEBM - Transp. Econ., Business and Mgmt	MSc Transport and Business Management	2	100+60	16364
United Kingdom	Imperial College London	TEBM - Transp. Econ., Business and Mgmt	MSc Transport - Extension Modules in Business Management	2	60	22750
Germany	Universität Duisburg Essen	TP - Transport Policy	MSc Public Transport Management	4	120	10000
The Netherlands	TU Delft - University of Technology, Policy and Management	TP - Transport Policy	MSc Engineering and Policy Analysis	4	120	12500
Germany	TUM - Technische Universität München	TPM - Transp. Plan. and Modelling	MSc Transportation Systems	4	120	1184
The Netherlands	TU Delft - University of Technology, Policy and Management	TPM - Transp. Plan. and Modelling	MSc Transport, Infrastructure and Logistics	4	120	12500
Sweden	KTH Stockholm	TPM - Transp. Plan. and Modelling	MSc Transport Systems	4	120	no info (free?)
Switzerland	ETH Zurich	TPM - Transp. Plan. and Modelling	MSc Spatial Development and Infrastructure Systems	4	120	1034
United Kingdom	University of Leeds - Faculty of Environment	TPM - Transp. Plan. and Modelling	MSc Transport Planning and Engineering	2	60	16718
United Kingdom	University of Leeds - Faculty of Environment	TPM - Transp. Plan. and Modelling	MSc Transport Planning	2	60	16718
United Kingdom	University of Leeds - Faculty of Environment	TPM - Transp. Plan. and Modelling	MSc Transport Planning and the Environment	2	60	16718
United Kingdom	University of Southampton	TPM - Transp. Plan. and Modelling	MSc Transportation Planning and Engineering	4	120	3873
United Kingdom	Newcastle University	TPM - Transp. Plan. and Modelling	MSc Transportation Planning and Policy	2	100+60	16364
United Kingdom	University of Westminster	TPM - Transp. Plan. and Modelling	MSc Transport Planning and Management	2	60	12205
United Kingdom	Edinburgh Napier University	TPM - Transp. Plan. and Modelling	MSc Transport Planning and Engineering	2	60	11479
United Kingdom	Imperial College London	TPM - Transp. Plan. and Modelling	MSc Transport - Extension Modules in Sustainable Development	2	60	22750
United Kingdom	Imperial College London	TPM - Transp. Plan. and Modelling	MSc Transport (elective stream)	2	60	22750
United Kingdom	Imperial College London	TTI - Transp. Techn. - Infrastruct.	MSc Transport (elective stream)	2	60	22750
Switzerland	ETH Zurich	TTI - Transp. Techn. - Infrastruct.	MSc Civil Engineering - Transport Systems	4	120	1034
Switzerland	EPF Lausanne	TTI - Transp. Techn. - Infrastruct.	MSc Civil Engineering - Transportation and Mobility	4	120	963
United Kingdom	Newcastle University	TTI - Transp. Techn. - Infrastruct.	MSc Transport Engineering and Operations	2	100+60	16364

3.1.6. Educational initiatives

May 08 – Students attend some workshops on Job Placement organized by the company Hire & Trust (Dr Fraga Nuno).

Jun 08 – Session of presentation of the 2007/08 students to the partner companies.

Nov. 2008 – Workshop de Team Building e Leadership at Nov 7 and 8 with company Action Coach.

Feb 2010 – Melanie Parker from the Global Education and Career Development Center of MIT organized two sessions with CTIS Students and one session with the partner companies about Job Placement.

Feb 2011 – Melanie Parker from the Global Education and Career Development Center of MIT organized two sessions with CTIS Students and one session with the partner companies about Job Placement.

A set of organized talks by guest speakers from the industry sector was organized for the CTIS students over the years, and which are described in the following three tables.

Talks in transportation systems for the academic year 2007/08

Date	Name	Company	Theme
15-02-2008	Jan Blomme	Port of Antwerp	Dr. Jan Blomme, gave a lecture about the business model followed by this port, and the kind of agreements the institution establishes with port operators and with the multiple suppliers
13-03-2008	Vístulo de Abreu and Luís Machado	President and Vice-President of GATTEL	the Government agency in charge of the preparation and management of the PPP contract for the Vasco da Gama bridge in Lisbon
17-03-2008	Harry Dimitriou	Omega Centre	The Omega Centre is the Centre for Mega Projects in Transport and Development, at University College London
07-04-2008	Gunnar Johansson	Industry Consultant at IBM Sweden	Dr. Gunnar Johansson Industry Consultant at IBM Sweden, technical responsible for the Stockholm Reduce Road Traffic solution.
10-04-2008	João Portela	BRISA	
18-04-2008	António Luzia and João Paulo Araújo	Transdev	The new light rail projects in which Transdev is participating in Europe
21-04-2008	Herbert Seelmann Ricardo Nunes	Siemens	

Talks in the transportation systems during 2009.

Date	Speaker	Company	Theme
16-12-2009	Stefan van der Speck	Delft University	Public Design: Public Space, Public Domain. Activity Patterns in Public Space
11-03-2009	Pierre Genton	Internacional Arbitrator in the construction industry	International Arbitration in conflicts of Mega Projects
19-03-2009	Daniel Cadet	Alstom	ALSTOM Innovation Culture - Bringing Technology Further
27-03-2009	Tiago Rodrigues	REFER/RAVE	Business Models for high-speed rail infrastructures in Portugal
03-04-2009	Francisco Ferreira	DGINFSO - European Com.	Information and Communication Technologies for Transport
15-04-2009	Werner Rothengatter	University of Karlsruhe	Stuttgart 21 & some stories from the book "Megaprojects and Risk"
21-05-2009	João Portela	BRISA	

Talks in the transportation systems area during 2010

Date	Speaker	Company	Theme
16-03-2010	Eng. Carlos Mota Santos	Mota-Engil	Business Models for Public-Private Partnership in Road Concession
29-03-2010	Eng. Jorge Sales Gomes	BRISA	The model of entrepreneurial innovation in BRISA
12-04-2010	Prof. Jonas Eliasson	Centre for Transport Studies Stockholm	The urban charging scheme in Stockholm: main steps and lessons of this experience
19-04-2010	Eng Carlos Fernandes	REFER/RAVE	The Portuguese project on High Speed Rail: key characteristics and business model
23-04-2010	Dr. Thomas Linder	Road administration of Bavaria	Realization of a bypass within the German federal highway network

Study Tour 2008

In 2008, the first ever group of Complex Transportation Infrastructure Systems (CTIS) students participated in the first annual “CTIS Technical Tour,” accompanied by Prof. José Viegas. Students visited nine different agencies and cutting edge projects in France, England, Switzerland and Germany. This technical tour was designed to give students a firsthand look at the types of projects and opportunities available for graduates of the program, as well as to familiarize them with some basic technologies and concepts in a real world setting.

In France, students had three tour stops:

- TGV EST (Paris - <http://lgv-est.com/>). Students experienced a High Speed Rail link that significantly reduces travel times between Paris and the East of France. Students have been made privy to information including contractual agreements, financial documents and various regulatory documents that are key to understanding this innovative and complex project.
- Tramway at Boulevard des Maréchaux (Paris - <http://www.ratp.com/>). CTIS students visited the RATP, the state enterprise responsible for the implementation of this transportation system. Representatives of RATP described the major principals of this urban project, including financing, public participation, and the different phases of construction.
- Vélib (Paris - <http://www.velib.paris.fr/>). The one-way bicycle rental scheme in Paris became an innovative solution to stimulate the use of bikes as a regular means of public transport. CTIS students visited the department responsible for the Vélib project, where they received a detailed explanation of the business model as well as of the various stages of implementation of this project.

London

- Congestion Charge (London - <http://www.tfl.gov.uk/home.aspx>). The London congestion charge is a fee paid by car drivers entering the central area of London designated as the Congestion Charge Zone. Visiting Transport for London, the authority that manages London’s transport systems, students learned how the congestion charge was established, how it works, payment methods, how revenue is spent and the technical support required to keep the system working.

- Crosslink (London - <http://www.crossrail.co.uk/>). Crosslink is a new railway project for London and South-East England that will deliver an accessible, affordable, high-frequency railway service across the capital from 2017. Students were informed about the operating and financing challenges presented by this project.
- High Speed Railway Extension from Waterloo to St Pancras (London). The St Pancras Station was renovated and expanded and is now the new terminal for Eurostar trains to continental Europe, and thus the new international station in London. Students received explanations about this controversial change, and the reasons that led to it, as well as about the financing scheme and the operating concepts.

Bellizona

Gotthard Base Tunnel (Switzerland - <http://www.alptransit.ch/pages/e/>)

This is set to become the world's longest rail tunnel, creating a rail link for future travel through the Alps. Students visited the Alptransit Gotthard, the company behind this new transalpine rail route, where they could get explanations of all the stages of the process of building a 57 km tunnel, and they had the chance to visit the works and a section of the tunnel.

Stuttgart

- Stuttgart 21 (Germany - <http://www.das-neue-herz-europas.de/default.aspx>). CTIS' students were introduced to the "Stuttgart 21", the project that will transform Stuttgart's nineteenth century main railway station into a modern transit-hub.
- Stuttgart Airport expansion (Germany - <http://www.flughafen-stuttgart.de/sys/index.php>) CTIS students saw the project of expansion of the Stuttgart airport, the only major airport in the country with one runway. The solution of building a second runway is being studied and a decision should be announced soon. All details related with this complex project were explained during a lecture held at the airport, by the Chairman and the Technical Manager of the Airport company.

Study Tour 2009

In May 2009, the Complex Transportation Infrastructure Systems (CTIS) students participated in the second annual "CTIS Technical Tour," led by Prof. Jorge Pinho de Sousa, accompanied by Ms. Teresa Afonso. The students visited and learned about a number of transportation facilities, including ports, airports, logistics facilities, tramways, high speed rail systems, and one-way bicycle rental schemes in various European countries. The sites visited were as follows:

Barcelona Port and Logistics Platform (Spain)

Students learned about the ZAL facilities, big logistics platform of the Barcelona Port, and saw a presentation regarding the expansion of this port. This visit outlined the economical importance of intermodality in the operations and of the business model of the platform.

Port of Antwerp and railway station (Belgium)

The visit to the Port of Antwerp started with a presentation by Mr. Jan Blomme at Port Centre Lillo. Then the students had a guided visit of the Port. They learned about the physical distribution of mineral water and general cargo. They also visited the chemical cluster, the container handling, and the lockage. Students then visited the Central Railway Station to learn about its expansion. The

station is an incredible adaptation of a magnificent old building with modern facilities and quality of service.

RFF and TGV EST (Paris)

In a visit to RFF, the French Railway infrastructure manager, students have been made privy to information including contractual agreements, financial documents and various regulatory documents that are key to understanding this innovative and complex project. In the evening, in their way to Stuttgart, students experienced a High Speed Rail link that significantly reduces travel times between Paris and the East of France.

RATP (Paris)

CTIS students visited RATP, the state enterprise responsible for transportation in the Paris metropolitan area. Representatives of RATP presented the main strategic principles of the company, emphasizing the role of mobility, and describing some concrete projects such as the Tramway at Boulevard des Maréchaux. Issues such as the major principals of this urban project, including financing, public participation, and the different phases of construction, have been deeply discussed.

Vélib (Paris)

The one-way bicycle rental scheme in Paris became an innovative solution to stimulate the use of bikes as a regular means of public transport. CTIS students visited the department responsible for the Vélib project, where they received a detailed explanation of the business model as well as of the various stages of implementation of this project. The system, based on more than 20 000 bicycles and hundreds of docking stations, has a significant impact concerning the population mobility and in ecological terms.

Stuttgart 21 (Germany)

CTIS students were introduced to the "Stuttgart 21", the project that will transform Stuttgart's nineteenth century main railway station into a modern transit-hub. The near-invisibility in the city center of an extensive light rail system will be made possible by a tunnel construction program with the relocation of heavy rail tracks. Moreover "Stuttgart 21 will yield the opportunity for restructuring and accelerating services that will be felt across the country and on Europe's high-speed rail network."

Frankfurt Airport (Germany)

CTIS students had a guided visit of Frankfurt airport by bus with very detailed explanations regarding the expansion of this airport. During this bus trip in the airport, students visited the Terminals, the logistic center, and other infrastructures. After this guided visit, they saw a 3D presentation at Fraport facilities related to the expansion of the airport.

Study Tour 2009/10

October 2009

Visit to the construction of the final section of CRIL / IC17, Buraca - Pontinha

May 2010

The students visited a project in Germany and Spain:

Munich

A9 – students visited the proposed demolition and reconstruction of a section of the motorway viaduct, built in the 70s. The project is interesting because of the complexity of construction and number of transport that pass by. The tram and subway lines, local streets, as well as various communications hinder the implementation of this project.

Traffic control center of the highway in southern Bavaria - students saw the implementation of many traffic control concepts they learned in class and were impressed with the level of automation in the center.

Munich Airport - students got to know the classification system of baggage and other places of the airport

Madrid

Atocha Railway Station - students became aware of the expansion project to increase capacity of high speed trains.

Traffic Control Center for High-Speed Rail Network – students visited the control room and Central Planning and Operations, where he got to know the network and plans for the future, including high-speed line Madrid-Lisboa.

Zaragoza

Students visited a logistics platform, which is in the local charge transfer, and a center for innovation in logistics.

3.2.Sustainable Energy Systems

3.2.1. Overview

Since 2007, the Business Engineering Master's in Sustainable Energy Systems has graduated 64 students over the course of three editions. The students that seek this program usually fit in one of these profiles:

- Professionals working on energy companies (examples from GALP, EDP, EFACEC, PARTEX) and supported by the companies that look for deeper knowledge on systems integration and energy policy;
- Professionals working on companies whose core business has not been energy but provide services for energy companies (infrastructures, consulting, IT). From this group, some are supported directly by the company, others are not but are trying to integrate or develop new business areas within the company;
- Professionals working on companies which have nothing to do with energy management, but who want to promote a career change.

Most of the students with non-engineering background belong to the first two groups. Most of the students from the third group have an engineering background from environment engineering.

The students graduating from the first group usually remain at the same company. Students graduating from the second group usually have evolved within the company. Examples of success from this group include a senior manager from the Energy & Utilities Industry business area from NOVABASE that is currently responsible for the Smart Grids project which includes building partnerships, buying companies / operations and also innovation. Another former student, who was the manager of the installations group from João Jacinto Tomé – a company that builds and manages infrastructures - is now the head of the innovation department and is developing a new business area on energy services. Many graduates from the third group were already able to make career changes they were planning beforehand. Some of the successful cases from this group include two alumni that have become senior managers at regional energy and environment companies (ARENA in Azores and OESTE Sustentável in west region of Portugal) and a third one became the head of the technical department of APREN – Portuguese Renewable Energy Association.

In general, the non-engineering students indicate that an important outcome of the program lie in the development of a clear understanding of the energy market in Portugal (main actors, value chain, drivers), as well as to know who is who in the industry. The engineering students indicate that the main outcomes are not only the management tools they learned in project evaluation or risk management, but also the deeper technical knowledge on subjects such as energy in transports, project evaluation and business planning, or energy management in buildings. Graduates also indicate that attending this program has enabled them to be aware and explore at a deeper level their own skills to deal with complexity, innovation, negotiation and strategy. They very much value the experience to work with colleagues from all over the world, which they report has increased their willingness to engage in international projects, and to deal with many different but correlated perspectives and different contexts, which all together allows them to reach integrated results.

In summary, the main advantages of the program are the opportunity to develop an entrepreneurship spirit and a professional and an academic network, all of which create new job opportunities for the SES students.

The success of the program and its cross-cutting curricula in engineering and management sciences is recognized either by the companies sponsoring their employees or the new employers of the SES graduates.

João Nuno Mendes, Director of Innovation of GALP Energia who has sponsored already three of his employees to attend the SES MBE says:

“The SES program was very successful in providing technological expertise in sustainable energy systems to our collaborators with a background in management and social sciences.”

António Sá da Costa, President of APREN (Portuguese Renewable Energy Association), who hired two of our graduates expresses his opinion about the SES MBE:

“My experience with the SES graduates is extremely positive. This program offers a very important systems perspective on energy problems. ... (t)he program provides a set of tools and training in management sciences for people with an engineering background, and which are very important to deal with the diversity of problems that the energy sector faces today.”

Coordinators of Sustainable Energy Systems

António Gomes Martins, Faculty of Sciences and Technology, University of Coimbra

António Vallera, Faculty of Sciences, University of Lisbon

António Vidigal, EDP (MBE director)

Carlos Silva IST, Technical University of Lisbon (MBE director)

João Peças Lopes, FEUP, University of Porto

David Marks, Dept. of Civil and Environmental Engineering, MIT (MBE director)

3.2.2. Structure

The Business Engineering Master's in Sustainable Energy Systems is a one-year program offered at the Technical University of Lisbon (IST/ISEG) and the University of Porto (FEUP) with a common core curriculum and common guidelines but with some local differences in terms of curricular structure.

FEUP

The Business Engineering Master's at FEUP is a one-year program addressing multidisciplinary core areas in energy systems. It offers three base graduation profiles, which share a considerable number of courses:

Profile A: Energy Systems Planning

Profile B: Sustainable Cities and Regions

Profile C: Advanced Electric Networks

In each semester students must choose 3 of the mandatory courses and 1 of the optional courses in a way to sum up a total of 60 credits (ECTS). Most courses are shared with the PhD Program. The courses are organized in 4 main graduation profiles, as detailed in table below:

Structure of the SES business engineering master's program at FEUP

Course	Profile	ECTS	Mandatory/ Optional	Semester
Energy, Environment and Sustainability + thematic work	A,B,C	7.5	Mandatory	1st
Energy Planning	A,B	7.5	Mandatory	1st
Energy Markets and Regulation	C	7.5	Mandatory	1st
Analysis and Simulation of Thermal Systems	A,B	7.5	Mandatory	1st
Signals, Dynamics and Control	C	7.5	Mandatory	1st
Introduction to Economics *	A,C	6	Optional	1st
Economics of Natural Resources and Environment *	A,C	6	Optional	1st
Projects Evaluation and Externalities *	B	6	Optional	1st
Computational Intelligence and Power Systems	C	7.5	Optional	1st
Seminar	A,B,C	22.5	Mandatory	2nd
Energy Efficiency	A,B	7.5	Mandatory	2nd
Market Simulation	C	7.5	Mandatory	2nd
Energy Demand Side Management	A,B	7.5	Mandatory	2nd
Electrical Systems with Renewables	C	7.5	Mandatory	2nd
Optimization and Decision Support Techniques	A,C	7.5	Optional	2nd
Energy in Buildings	B	7.5	Optional	2nd
Forecasting	C	7.5	Optional	2nd
Methods for Optimal Power Flow	C	7.5	Optional	2nd
Wind Energy	C	7.5	Optional	2nd

* Modules offered by UTL/FCUL

IST/ISEG

The Business Engineering Master's at IST/ISEG is a one-year (280-hour) program addressing multidisciplinary core areas in energy systems, including:

- Economics, management science and policy
- Environmental analysis and assessment
- Energy systems
- Energy technologies

Each student can create a unique curriculum to fulfill her/his individual interests. Guided by a faculty member, the student is allowed to choose from a pool of optional courses in order to complete 48 to 60 ECTS units, including the two mandatory courses (please see table below).

Structure of the SES Business Engineering Master's Program at IST/ISEG

Scientific area	Course	ECTS	Mandatory/Optional	Semester
Introductory courses	Introduction to Economics	6	Optional	1st
	Introduction to Engineering	6	Optional	1st
Economics	Economics of Natural Resources Environment	6	Optional	1st
	Econometrics	6	Optional	1st
	Energy Systems Economics and Modeling	6	Optional	1st
	Risk Management	6	Optional	2nd
	Projects Evaluation and Externalities	6	Optional	2nd
	Regulation Theory	6	Optional	2nd
Environment	Energy, Environment and Sustainability	6	Optional	1st
	Energy in Transportation	4,5	Optional	1st
	Ecological Economics	6	Optional	2nd
Energy Systems	Energy Management	4,5	Optional	1st
	Energy Systems Integration	6	Optional	2nd
	Optimization of Energy Systems	6	Optional	2nd
Energy Technologies	Seminars I	3	Mandatory	1st
	Seminars II	3	Mandatory	2nd
	Energy in Buildings	6	Optional	2nd
	Nuclear Energy	6	Optional	2nd
	Renewable Energy Resources	6	Optional	2nd

3.2.3. Student highlights

Here are the comments of two alumni of the Master's of Business Engineering in Sustainable Energy Systems who benefited directly from attending this program with a very positive impact in their career development.

Isabel Abreu was a student of the 2008/09 edition of the SES MBE program and she changed her professional career after graduating from this program. Here are her comments about this change.

'If it wasn't for my experience at the Master's of Business Engineering in Sustainable Energy Systems I would not be now the head of the technical department of the Portuguese Renewable Energy Association (APREN). Of course one of the main reasons why I got the job was my pro-active attitude, which didn't come from the program, but that alone would not have been enough. The program provided me the knowledge in energy matters and the driver to contact my current boss, and afterwards to get in touch with APREN. This program was perfect for the career change I was looking for.'

Isabel Abreu, APREN

Maria Carvalho was a student of the 2008/09 edition of the SES MBE program and she changed her professional career after graduating from this program. Here are her comments about the positive effect that attending this program had in her professional life.

Above all the SES degree developed my entrepreneurship spirit, which I think, is being everyday day more appreciated in the job market in Portugal. In addition, the networking with the MIT community and companies associated with it gave me a special position into getting a new job in the energy

context. In May 2010 I became the CEO of the Regional Energy and Environment Agency for the West Region of Portugal – Oeste Sustentável. This is a freshly started Agency, nearly one-year old. My job has been to build a new team for the Agency, to develop its brand, conceive new projects and activities along with building a close relation with all its associates. As a CEO my main responsibilities include coordination of all activities/projects and resources, developing the Strategy and Annual Activities Plan, Budget Controlling and Communication with European Commission. Along with this new position, I am now experienced in developing business plans for energy projects, which is a new major asset in my professional life.

The Sustainable Energy Systems MBE degree improved my motivation and drives to learn as much as possible all the time and to use all of my abilities to succeed in tackling complex projects. From the experience of working with colleagues from all over the world, I developed a great willingness to engage in major international projects, to deal with different perspectives, different contexts and to be able to reach integrated results. I am now more passionate for complexity, innovation, negotiation and strategy.

Maria Carvalho, Regional Energy and Environment Agency for the West Region of Portugal

3.2.4. Alumni profiles

This section presents the profile of some of the alumni of the Master's of Business Engineering in Sustainable Energy Systems (SES).

Name: **Isabel Martins Ferreira Cancela de Abreu**

Program: SES

Year of graduation: 2009

Previous professional situation

Account and Project Manager at YDreams, responsible for projects using interactive technologies to communicate educational content.

Post-graduation professional situation

Head of Technical Department at APREN – Portuguese Renewable Energy Association.

Main responsibilities: collection and treatment of national and international energy data; coordination of APREN studies; legislation overview; follow up of internal technical matters of APREN's associates; support to the board and advisory panel of the Association; management of events; in charge of European projects; preparation of communication strategy; represent APREN at national and international events; negotiate protocols with other energy entities

Learning outcomes

Basic energy concepts, update on energy "hot issues", overview of national and international current energy context, technology information, entrepreneurship, access to energy experts, economic and financial basic concepts

Competitive advantage

If it wasn't for MIT PORTUGAL I would not be working at APREN. Of course one of the main reasons why I got the job was my pro-active attitude, which didn't come from the program, but that alone would not have been enough. The MIT PORTUGAL provided me the knowledge on energy matters and the driver to contact my current boss, and afterward get in touch with APREN. This program was perfect for the career change I was looking for.

Name: **Maria Susana Carvalho**

Program: SES

Year of graduation: 2009

Previous professional situation

Since 2007, I have been working at Ferconsult, S.A.: a company dedicated to consultancy, studies and project conception in transportation engineering, where I have been working as a Project Director and Business Developer. My main responsibilities include supporting the development of the Strategy and Activities Plan of the Company, coordinating the development and follow-up of proposals, budgets and contracts, project managing, team management and communication

Post-graduation professional situation

Besides improving my skills at Ferconsult, S.A. in May 2010 I engaged a new challenge starting to work as CEO at the Regional Energy and Environment Agency for the West Region of Portugal – Oeste Sustentável. This is a freshly started Agency with almost one-year lifetime. My job was to build a new team for the Agency, to develop its brand, conceive new projects and activities along with building a close relation with all its associates. As CEO my main responsibilities include coordination of all activities/projects and resources, developing the Strategy and Annual activities Plan, Budget controlling and Communication with European Commission.

Learning outcomes

Some of the most effective knowledge I got to put into practice is related with Energy efficient Transportation, Project evaluation and business plans, Energy Policy, Energy Management in Buildings and Industrial sectors, Energy Efficiency in households and Renewable Energy projects development.

The MIT PORTUGAL degree improved my motivation and driven force to learn as much as I can and to use all of my abilities to obtain success in complex projects. From the experience of working with colleagues from all over the world, I developed a great willingness to engage in international major projects, to deal with different perspectives,

Competitive advantage

Above all the MIT PORTUGAL degree developed my entrepreneurship spirit, which I think, is being everyday day more appreciated in the job market in Portugal. In addition, the networking with the MIT community and Companies associated with it gave me a special position into getting a new job in the Energy context. Along with that new position, I am now experienced in developing business plans for energy projects, which is a new major asset in my professional life.

Name: **Nelson Teodoro**

Program: SES

Year of graduation: 2010

Previous professional situation

Novabase | Senior Manager | Member of the Energy & Utilities, Engagement Manager for EDP, EDA and Galp.

Post-graduation professional situation

Novabase | Senior Manager | Member of the Energy & Utilities Industry, responsible for the Smart Grids offer, meaning building partnerships, buying companies / operations and also creating innovation inside Novabase

Learning outcomes

It was very important, since I'm not an engineer, to have a clear overview of the energy market (main actors, value chain, drivers, ...) but also to know who is who in the industry.

Competitive advantage

It was important since I got a very good network of professional contacts.

Name: **Nuno Afonso**

Program: SES

Year of graduation: 2009

Previous professional situation

Before taking the MIT Portugal Program, I was project manager in the Electrical Infrastructures area at João Jacinto Tomé company. I was responsible for Project management in the electric sector.

Post-graduation professional situation

Nowadays I'm a business unit manager in the electric infrastructures area and also leading a Department of Innovation and Development in the energy area for the same company. This department is mainly focused on Renewable Energy Technologies and Energy Management and we're focused on new business areas and models for the energy sector. I'm responsible for business and project development and management in these fields.

Learning outcomes

The MIT Portugal program was very important because it provided me with an increase of knowledge on energy policies and technologies, sustainability, energy management, project evaluation and the Portuguese energy sector.

Name: **Nuno Ferreira Domingues**

Program: SES

Year of graduation: 2009

Previous professional situation

Senior Project Manager

Post-graduation professional situation

Coordinator of Green Islands Project on behalf of the Government of Azores/ President of the Regional Agency for Energy and Environment of Azores / Regional Director for Air and Sea Transportation of Azores

Learning outcomes

Energy and renewable energies technologies

Competitive advantage

Training in energy and renewable energies technologies; combined with the track record in project management and in international markets gave a very good portfolio of engineering; it was key to start managing the Green Islands Project on behalf of the Government of Azores.

3.3. Technology Management Enterprise

3.3.1. Overview

The Business Engineering Master's in Technology Management Enterprise (TME) is a joint degree offered by the Technical University of Lisbon, University of Minho and the University of Porto and leads to a 3rd Cycle Bologna Diploma, which.

TME is a 15 months modular intensive part-time course that trains technical managers for product development and production systems. Students learn management skills including human resources competences for bridging complex technical and management issues under a demanding production environment. The interdisciplinary engineering and management-based curriculum culminates in a thesis targeting an industrially oriented topic.

TME is targeting technical staff of Portuguese and European companies (with engineering education) aiming at developing a career in technical or production management, with 2-3 years of practical experience. The TME Advanced program is designed to allow the student to attend an academic program while continuing his/her professional activity.

TME graduates will be capable of leading multidisciplinary teams in product development and industrial operations and to address multiple challenges in engineering design and manufacturing, including:

- Innovative product development,
- Advanced processing / production solutions,
- Optimization of production processes under an integrated perspective of the overall product cycle.

Courses are concentrated in six full time blocks of two weeks each, with one and half month of interval between two consecutive blocks. This formula allows students to keep their current professional activity, while advancing and maturing their skills with the TME curriculum and innovation environment.

The academic schedule format is extremely popular with students because the two week periods engender intense work environments and interpersonal relationships among the cohort of students.

There has been a serious effort to couple the educational program with research activities at Portuguese and other European Industrial Affiliates. TME includes, for instance, a thesis that is related to the students' work at a Portuguese company.

We have also implemented new and novel education delivery mechanisms and the evaluation of those mechanisms. These include the rotation of faculty and students to the three Portuguese universities in this scientific domain along with close participation of MIT faculty and the delivery of course content in an intensive two-week modular format. MIT and Portuguese faculty have collaborated to evaluate the effectiveness of the EDAM teaching format in comparison with a more traditional length format and have found EDAM format has a positive impact on the students.

The TME curriculum was re-structured after two editions based on feedback from students and faculty. The new curriculum has more of an emphasis on engineering systems and more tightly integrates TME and LTI (Leaders for Technical Industries PhD) students. At present TME and LTI lecturing schedules are coincident, enabling a more challenging and richer environment for learning and networking, with students of different backgrounds and professional experiences.

We also have invited students from other scientific domains to participate in EDAM's course on Leadership. Furthermore, faculty from the EDAM and Bioengineering Systems areas collaborated on the development of the Innovation Management Course, and EDAM faculty have taught a Bioengineering Systems course.

What is learned in the courses and along the program is also important for student's professional careers, as has been highlighted by the participants.

The impact of the TME is clear from this comment made by Pedro Portela, a student from the first edition in 2007/08:

'... I believe the Engineering Design and Manufacturing Systems course together with the course on Innovation Management taught by Luis Perez-Breva were the perfect closing for the program. Only now have I clearly seen the «big picture» and what was intended with the whole program. Engineering Systems is starting to make sense for me and I'm starting to find it a fascinating topic. The complexity of a leadership role and making good decisions is becoming clearer now as is the fact; indeed, Portugal desperately needs these kinds of leaders. In fact, I am so overwhelmed by this new perspective that I am already considering a career change; during the program I learned also a lot about myself. My ability to work under tight timings, to work in team, I learned that I love doing presentations and gained a lot of confidence doing them, I learned that sometimes you just have to do the job you are assigned to and put all your energies into it... whether you like it or not.'

More recently, Jorge Ribeiro, 2009/10 TME also expressed his positive impression on the program:

'I value the choice of the TME, mainly for assuring a close link to the Industry within a multicultural and multidisciplinary environment, crucial nowadays. The approach of the EDAM focus area, highlighting the Engineering Systems and the Product Development has also proved very enlightening.'

João Ricardo Gonçalves, Development Engineer from Celoplás, and TME student in 2007/08 has said what follows about the TME Master's:

From my previous TME experience I can highlight, in particular, the Product Design and Development course, as well as the industrial and pragmatic approach throughout the program, and which I think are some of its greatest assets. In fact, this is the most distinctive feature of the TME program when compared with more traditional academic advanced graduations in Portugal. The interconnection of academia and industry has been central to my involvement in the TME.'

The commitment of Industrial Affiliates to the future of the program is evidenced by the comments of António Cardoso Pinto, the CEO of Adira, a manufacturing equipment production company:

‘TME is a good program that complements very well the technical expertise of our people. This is an evaluation based on our experience of two TMEs in two different years. I expect to continue to benefit from this program and to send one new candidate per year.’

Another distinctive example is the one provided by João Cortez, the CEO of Celoplás:

‘Apart from the different know-how and several other gains (which will be assessed and reflected within a short and medium terms), it is possible to emphasize the change in attitude, the pro activity enhancement, such as working throughout weekends. The investment in TME is thus undeniably positive and rewarding.’

Coordinators of the Engineering Design and Advanced Manufacturing

António Torres Marques, FEUP, University of Porto (TME director)

Chris Magee, Engineering Systems Division, MIT

Joel Clark, Department of Materials Science and Engineering, MIT (TME director)

Manuel Freitas, IST, Technical University of Lisbon

Olga Carneiro, School of Engineering, University of Minho

3.3.2. Structure

The structure of the Master’s of Business Technological Management Enterprise (TME), is described in the table below:

Structure of the TME Master’s of Business Engineering

Course	ECTS	Mandatory/Optional	Semester
Product Development	6	Mandatory	1st
Technology Evaluation and Selection	6	Mandatory	1st
Integrating Technology & Management	6	Mandatory	1st
Operations Management	6	Mandatory	1st
Advanced Technologies	6	Mandatory	1st
Engineering and Manufacturing Systems	6	Mandatory	2nd
Management for Engineering	6	Mandatory	2nd
Innovation Management	6	Mandatory	2nd
Production Management	6	Mandatory	2nd
Leadership	6	Mandatory	2nd
Research Project	30	Mandatory	

TME students are required to take a total of 90 ECTS: 60 ECTS from the curricular component (all 10 courses are mandatory) and the remaining 30 ECTS from the Research Project.

TME students must write a Research Project that describes original work conducted over the course of the Master’s of Business Engineering program project or a derived company-related activity, but either way the topic and content should be under the umbrella of the TME program theme and consistent with the scope of the EDAM focus area. The development of the thesis will most likely be supervised by an EDAM Professor but not necessarily; this person may try to engage an MIT faculty member.

The TME student is expected to write a Research Project proposal of approximately 2-3 pages outlining the research objectives, plan, and timeline. It should be jointly signed by the student and the Research project supervisor and should be submitted to the TME committee for review by July 31st. The TME committee will provide feedback on the proposal by August 31st.

The Research Project supervisor(s) and the students shall meet at regular intervals throughout the fall: e.g., with monthly meetings to report on progress.

The Research Project should be submitted to the TME committee by December 31st and the results will be presented to the sponsoring company by January 31st in the presence of the thesis supervisor.

3.3.3. Student's highlights

Here we offer the comments of two alumni of the Master's of Business Engineering in Technology Management Enterprise who benefited greatly from attending this program and had a very positive impact in their careers.

Vitor Martins, from the 2008/09 TME sustains the following about his participation:

'Before joining TME, I worked as senior engineer, responsible for the launch of the VW Scirocco in the Pilot Plant at the company Volkswagen Autoeuropa in Palmela, Portugal. In the middle of the academic year I was transferred to the Final Acceptance Quality area Quality: I participated in a program "Checking Process Team" with the Director General of Production. Moreover I was engaged in the coordination of a team for the planning and launching of a new project, enterprise application for quality control and intermediate points in the final check of your car and the repairs. In fact, being part of the TME was important for my professional life and it translated on a more efficient practice. The plant organization benefited directly from the work done together in the final thesis "Transportation Synergy," which will save 25% of the transportation costs and logistics. This was also a launching opportunity for a new way of "thinking" and transporting materials to and for the Volkswagen Autoeuropa Portuguese and other exporting companies. Even though I haven't directly progress in my job position, I feel available and better prepared to take on new professional challenges within the Volkswagen Autoeuropa and outside the factory, in other factories of the Group.'

Vitor Martins, Volkswagen Autoeuropa

Elizabete Pinho, from TMG Automotive, and a TME student from 2008/09 edition, also highlighted some points about TME:

'When I joined the TME, I was responsible for Product Development at TPE group of TMG Automotive. Today I am TMG Automotive Technical Director. From my participation in the 2008/09 TME I most value the global perspective on the product development and the awareness of the importance of project's several stages of development, as well as the importance of deadlines. I also learned more about the need to coordinate teamwork and to integrate different points of view in order to accomplish a given deadline.'

Elizabete Pinho, TMG Automotive

3.3.4. Alumni profiles

This section presents the profile of some of the alumni of the Master's of Business Engineering TME.

Name: **Elizabete Pinho**

Program: TME Technology Management and Enterprise

Year of graduation: 2010

Previous Professional Situation

Responsible for Product Development at TPE group in TMG Automotive

Post-graduation Professional Situation

TMG Automotive Technical Director

Learning Outcomes

- Global Perspective on the product development and the importance of a project's several stages of development
- The importance of deadlines
- The need to coordinate teamwork and to integrate different points of view in order to accomplish a given deadline

Competitive Advantage

I regret that the TME isn't more of a degree, since it is not a Master Degree nor a Phd, not even a MBA.

Therefore, today I would choose instead the LTI, since the schedule is quite similar and from the academic point of view – a PhD degree – is more attractive.

Name: **João Ricardo Gonçalves**

Program: TME Technology Management and Enterprise

Year of graduation: 2009

Previous Professional Situation

Celoplás Development Engineer

Post-graduation Professional Situation

No changes to be mentioned

Learning Outcomes

From my previous TME experience I can highlight, in particular, the Product Design and Development course, as well as the industrial and pragmatic approach, common to all EDAM, which I believe being among its clearest advantages.
In fact, this is the most distinctive factor feature of TME if compared to more traditional academic advanced graduations. The interconnection of academia and industry has been central to my involvement in the TME.

Competitive Advantage

The interconnection of academia and industry has been central to my involvement in the TME and a key factor to progress professionally and to address daily industrial challenges with a more comprehensive scope.

Name: **Vítor Martins**

Program: TME Technology Management and Enterprise

Year of graduation: 2009

Previous Professional Situation

Before joining TME, I worked as senior engineer, responsible for the launch of the VW Scirocco in the Pilot Plant at the company Volkswagen Autoeuropa in Palmela, Portugal.

At mid-MIT Program I was transferred to the Final Acceptance Quality area Quality:

I participated in a program "Checking Process Team" with the Director General of Production. Moreover I was engaged in the coordination of a team for the planning and launching of a new project, enterprise application for quality control and intermediate points in the final check of your car and the repairs.

Post-Graduation Professional Situation

No changes to be mentioned

Learning Outcomes

From my participation in the TME, I underline the fact that I developed a broader and more comprehensive vision of the international market and Portuguese companies. I also stress the importance of being in touch with research, know-how and methods used in the four universities involved in the Course. Other than that I also value how I gained know-how in fields such as programs to aid decision- making, construction of Business Cases and an overall more comprehensive and strategic vision of business planning.

Competitive Advantage

In fact, being part of the TME was important for my professional life and it translated on a more efficient practice. The plant organization benefited directly from the work done together in the final thesis "Transportation Synergy," which will save 25% of the transportation costs and logistics. This was also a launching opportunity for a new way of "thinking" and transporting materials to and for the Volkswagen Autoeuropa Portuguese and other exporting companies. Even thou I haven't directly progress in my job position, I feel available and better prepared to take on new professional challenges within the Volkswagen Autoeuropa and outside the factory, in other factories of the Group.

4. Faculty exchange: training the trainers

A very positive feature, and notable success, of the MIT Portugal network is the faculty exchange program. This program allows Portuguese faculty to spend a significant amount of time at MIT as Faculty Fellows in order to work closely with their MIT colleagues, make or expand valuable professional networks (both academic and research), develop specific skills that are essential for them to teach new courses and modules that were developed collaboratively with MIT within the MIT Portugal Program, and to absorb the culture of MIT's rich academic and research environment. In particular, Portuguese junior faculty visits to MIT have been highly influential in their impact on teaching practice, by permitting these faculty members to audit MIT classes and thus to gain a comparative perspective on how their subjects are taught and contextualized at MIT, and to acquire the competences to teach MIT courses at home.

To date, 27 new courses have been developed for teaching in MIT Portugal degree programs in Portugal, many of which introduce curricular elements that are novel to Portuguese engineering education. For example, an Engineering Systems Research Methods course, taught to PhD students in EDAM, was designed to lay a foundation for empirical research in the social sciences and engineering systems, introducing basic assumptions and underlying logics. Students become acquainted with a variety of approaches to research design, evaluate the products of empirical research, practice several common techniques, and develop their own research project. Faculty exchanges that permit Portuguese faculty to spend time at MIT working on these sorts of specific, challenging issues together with their MIT colleagues are critically important in building the human capacity and connections needed to make the program a success and have the expected impact. Two good examples of this type of exchange were Professors Joao Sousa and Joao Claro, who came to MIT during sabbatical stays specifically to be exposed to engineering systems approaches and practices.

Another excellent example of successful faculty exchange is the eleven Portuguese faculty that have visited MIT to take part in the MIT Entrepreneurship Center's Innovation Teams course – in which students develop commercialization strategies for cutting-edge technologies – and to bring lessons learned back home to their respective Portuguese universities. The I-Teams approach is a cornerstone of the curriculum developed by MIT Portugal's Bioengineering focus area. For example, Luísa Ferreira Lopes, Assistant Professor in FCTUNL, where she is the Chair of the Economics of Innovation post-graduate course, was a participant during the current Fall '09 academic term. Describing her experience at MIT, she said, "what is most striking about the I-Teams course compared to courses in Portugal is that the students lead the work, not the teacher. It is the students that are empowered to move their projects forward, with the support of the teacher – but without hand-holding."

Through the MIT Portugal Program, a new cadre of talented junior faculty has been hired and trained in MIT teaching pedagogy. A good example is Ligia Rodrigues, Assistant Professor, University of Minho, MIT Portugal Program Bioengineering Focus Area. Prof. Rodrigues applied in 2007 when MIT Portugal opened faculty positions. These positions are different in that they explicitly include a commitment to spend half their time doing research and half their time teaching.

MIT PORTUGAL Faculty Fellows						
Researcher		Dates of Visit		MIT Host		
Name	University	Start	End	Person	Focus Area	Subject of Research/visit
Aguiar Oliveira, Ana Isabel Ricardo	New University of Lisbon	6/15/2007	12/10/2007	Paula Hammond	BioEngineering	Sabbatical: chem engineering
Alves, Paula	New University of Lisbon	7/1/2009	9/1/2009	Danny Wang	BioEngineering	iTeams/Danny Wang research lab
Bernardo, Carlos A. A.	University of Minho	4/26/2009	6/15/2009	Joel Clark	EDAM	Sabbatical: EDAM research interactions
Carvalho, Patricia	Technical University of Lisbon - IST	9/1/2008	8/30/2009	Subra Suresh	BioEngineering	Cell and molecular mechanics in human diseases
Claro, Joao	Porto	8/25/2008	12/19/2008	Richard DeNeufville	Engineering Systems	Building relationships with ESD faculty, furthering his understanding of EngSys for transfer to PT university context
da Silva, Claudia Lobato	Technical University of Lisbon - IST	Fall 2008		Dava Newman	BioEngineering	Stem cell research
Duarte, Jose	Technical University of Lisbon - IST	9/1/2009	6/1/2009	William Mitchell	Energy	Design Lab
Ferreira, Frederico	New University of Lisbon	9/7/2009	12/5/2009	Cooney/Newman	BioEngineering	iTeams
Lages, Luis Filipe	New University of Lisbon	3/5/2007	5/31/2007	Dava Newman	BioEngineering	iTeams
Lages, Luis Filipe	New University of Lisbon	1/17/2010	7/31/2010	Charlie Cooney	BioEngineering	Sloan Lisbon MBA program
Lages, Carmen	ISCTE	1/17/2010	6/1/2010	Cooney/Newman	BioEngineering	iTeams

MIT PORTUGAL Faculty Fellows						
Researcher		Dates of Visit		MIT Host		
Name	University	Start	End	Person	Focus Area	Subject of Research/visit
Llusa, Fernanda	New University of Lisbon	1/29/2009	5/15/2009	Dava Newman	BioEngineering	iTeams
Lopes, Louisa	New University of Lisbon	9/1/2009	12/20/2009	Cooney/Newman	BioEngineering	iTeams
Prazeres, Miguel	Technical University of Lisbon - IST	3/1/2007	4/30/2007	Dava Newman	BioEngineering	iTeams
Rodriquez, Ligia	University of Minho	Spring 2008		Kris Prather	BioEngineering	iTeams
Rocha, Luis	University of Minho	3/8/2009	6/20/2009	Chris Magee	EDAM	Collaborative research and EDAM course development
Rocha, Isabel	University of Minho	3/1/2007	4/30/2007	Bruce Tidor	BioEngineering	iTeams
Silva, Carlos	Technical University of Lisbon - IST	10/6/2008	10/31/2008	David Marks	Engineering Systems	Collaborative research and EngSys and Energy networking
Saraiva, Pedro	Coimbra	3/1/2007	6/10/2007	Dava Newman	BioEngineering	iTeams
Sousa, Joao	Technical University of Lisbon - IST	9/1/2008	6/31/2009	Daniel Roos, Richard Larson	Engineering Systems	Building relationships with ESD faculty, furthering his understanding of EngSys for transfer to PT university context
Simoies, Ricardo	University of Minho	3/1/2007	4/30/2007	Chris Magee	EDAM	Collaborative research and EDAM course development
Silva, Arlindo	Technical University of Lisbon - IST	5/11/2009	9/1/2009	Chris Magee	EDAM	Collaborative research and EDAM course development

According to Prof. Rodrigues, “We also have different aims and challenges – other faculty keep doing their research. But for us, it is developing new relationships with MIT and for me, it is developing a new area of study for Portugal. These responsibilities are good practice for the future. For example, we had the Bioweek [conference] in Minho recently and my colleagues helped a lot in running the conference. The way the program is organized and taught is quite different from other doctoral programs we have [in Portugal]. I got to experience the MIT way of teaching courses first hand because I took I-Teams [a School of Engineering innovation course] and other courses, and I had the opportunity to see some of the MIT faculty teach classes. In this Bioengineering program of MIT Portugal the teaching is the same format as what is being done at MIT.”

The previous table lists the Portuguese faculty members that have spent significant time at MIT, with some basic facts about their stay.

5. Educational programs in numbers

5.1. Doctoral programs

5.1.1. Applications

In its four editions the doctoral programs have attracted a total of 1227 applicants. As shown in figure 3, this number has been progressively increasing and it reached its peak in the last edition (2010). The number of international applicants has dramatically increased since the first edition in 2007 (Fig. 4). Last year 62% of the applications came from candidates from 55 different countries other than Portugal (Fig. 5)

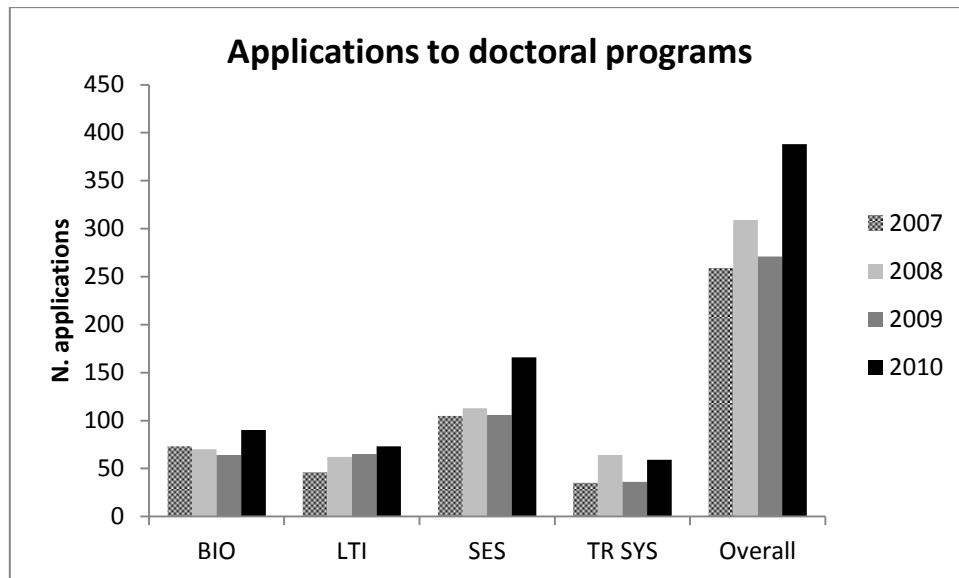


Fig. 3: Number of applications to doctoral programs over the past four years.

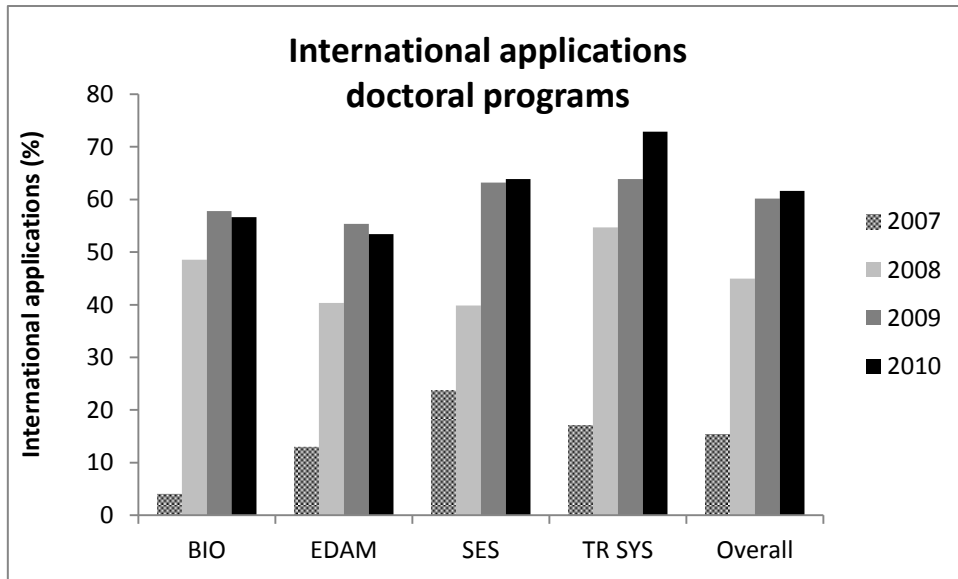


Fig. 4: Proportion of international applications to doctoral programs over the past 4 years. Fig. 4: Proportion of international applications to doctoral programs over the past 4 years.

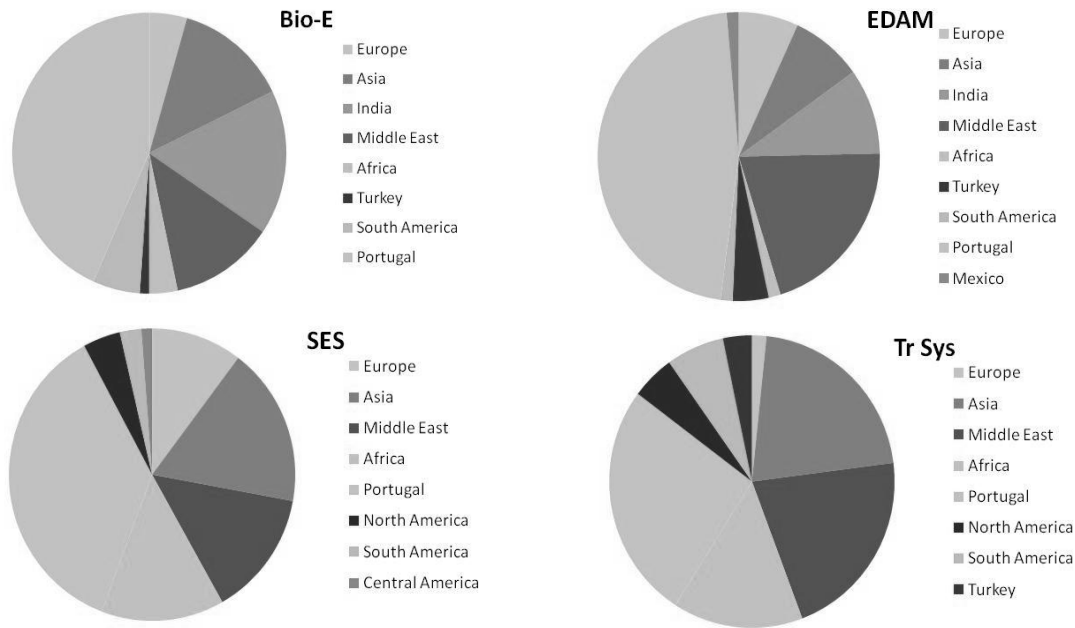


Fig. 5: Geographical origin of PhD candidates in 2010 for each PhD program.

5.1.2. Students

Currently the network has a total of 276 doctoral students of which 24% are international (Fig. 6 and 7). The international number of admitted students has been increasing progressively over the years and in the last two editions 32% of the admitted students were from outside Portugal. Students come from 44 different countries and 4 continents (Fig. 8). The Transportation Systems PhD is the program with a higher proportion of international students (56%).

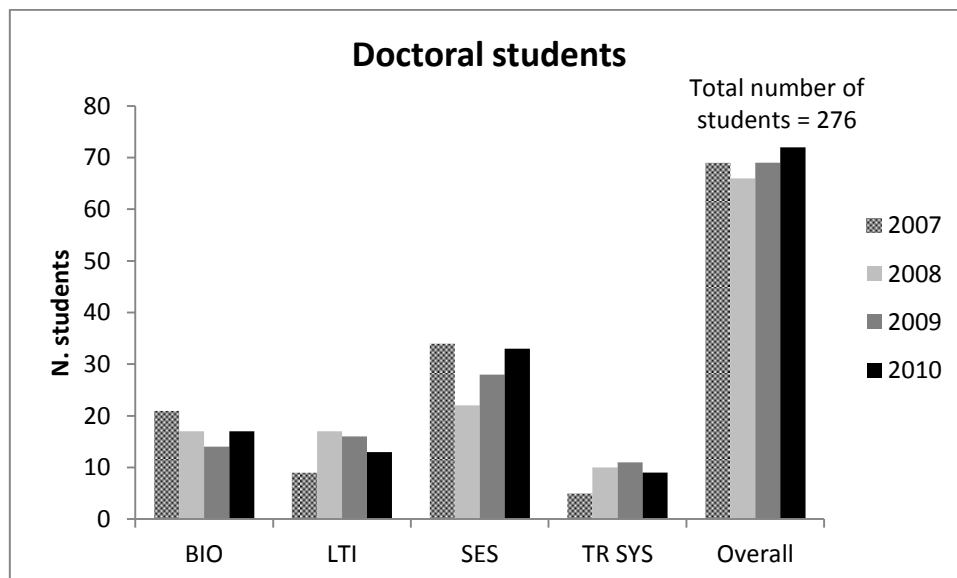


Fig. 6: Number of current doctoral students per year of admittance and program.

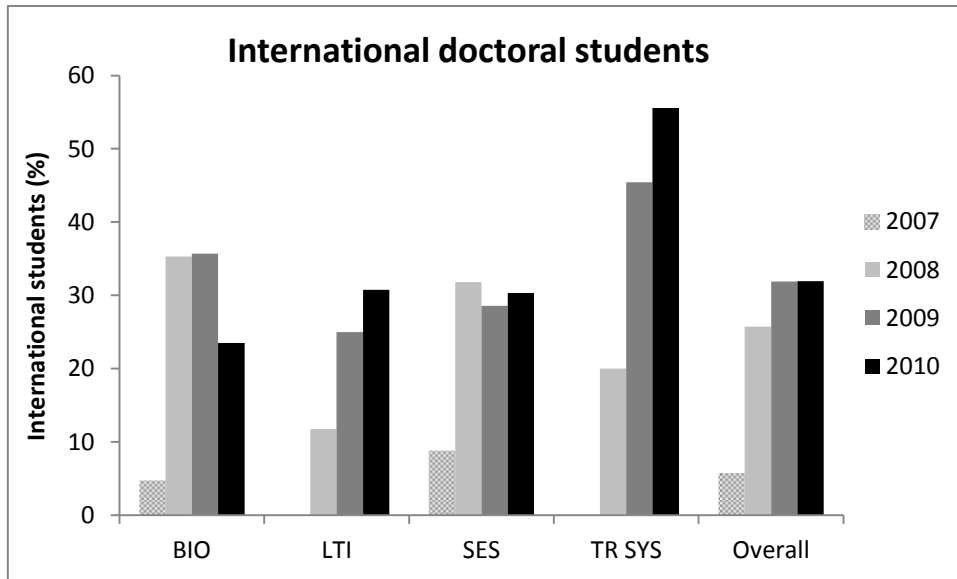


Fig. 7: Proportion of international doctoral students.

This multicultural and vibrant working environment enhances professional networking and collaboration, while also enriching the personal development of the PhD students.

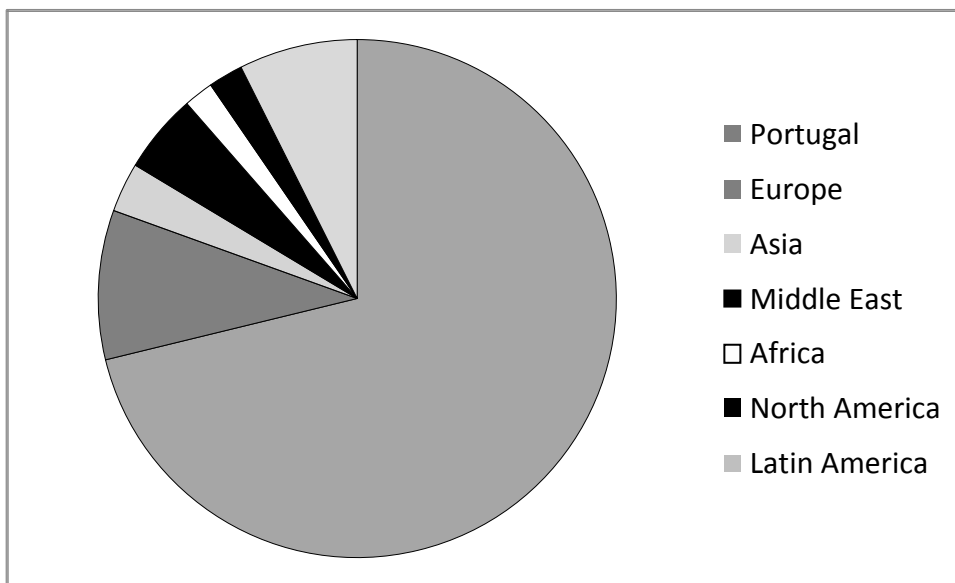


Fig. 8: Geographical origin of doctoral students.

5.1.3. Scholarships

The total number of scholarships awarded directly by FCT to the top candidates of the doctoral programs was 169. Figure 9 shows the figures for each academic year and per doctoral program. Other admitted students have applied, individually, to the national FCT PhD scholarship call and a total of 24 of them have obtained funding for attending the MIT Portugal PhD programs during the past 4 years (Fig. 10).

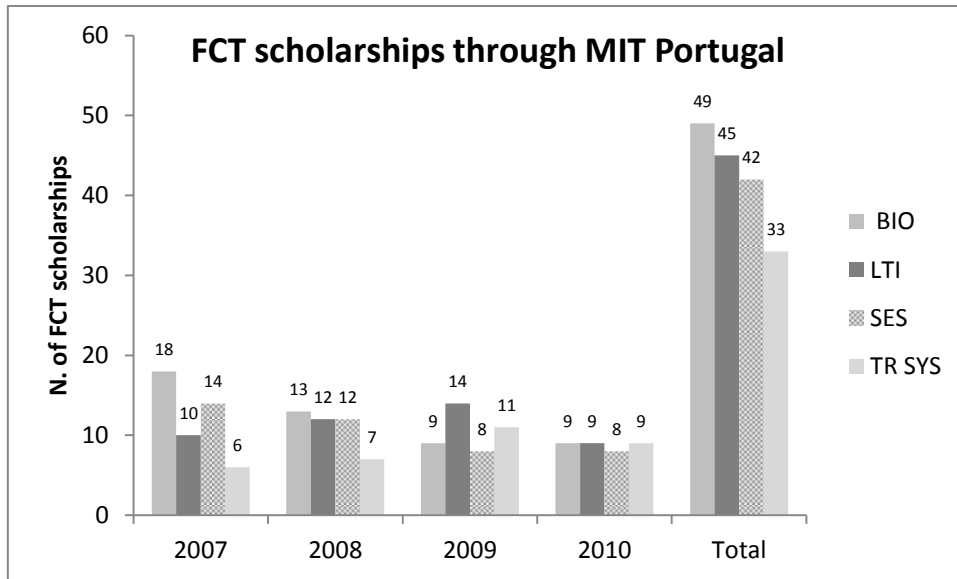


Fig. 9: Number of FCT scholarships awarded through the MIT Portugal network over the past 4 years for each program.

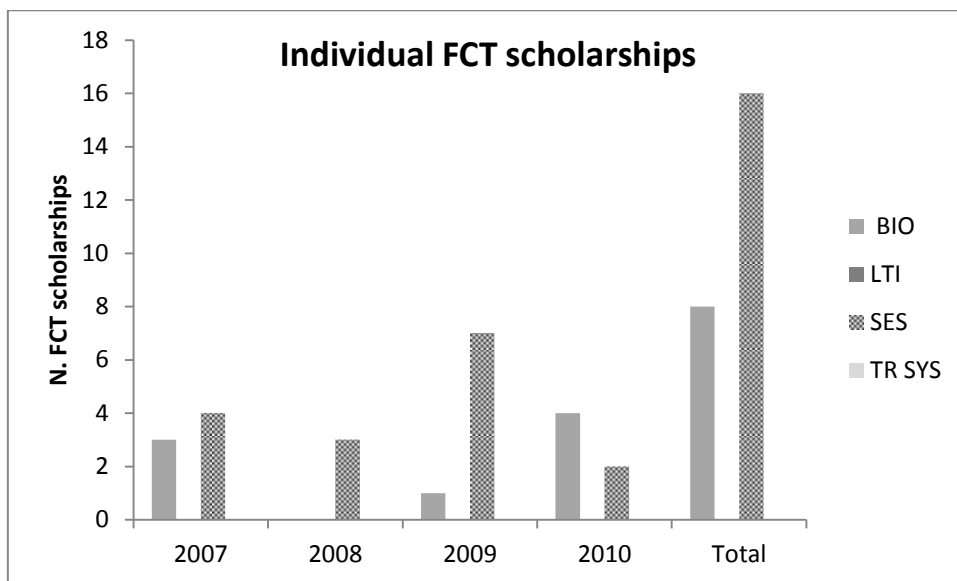


Fig. 10: Number of individual FCT scholarships awarded for each program. These scholarships were obtained through the FCT national PHD scholarship's call.

5.1.4. Selectivity

Students are selected through a rigorous admissions process. On average, only 26% of those who apply are admitted (Fig. 11). Many of the students come from world leading academic institutions such as MIT, Imperial College London, University of Michigan and ETH Zurich, and some also bring prior experience in international organizations, e.g. Volvo Sweden, PriceWaterhouseCoopers, the Office of the Prime Minister of France, and the World Resources Institute.

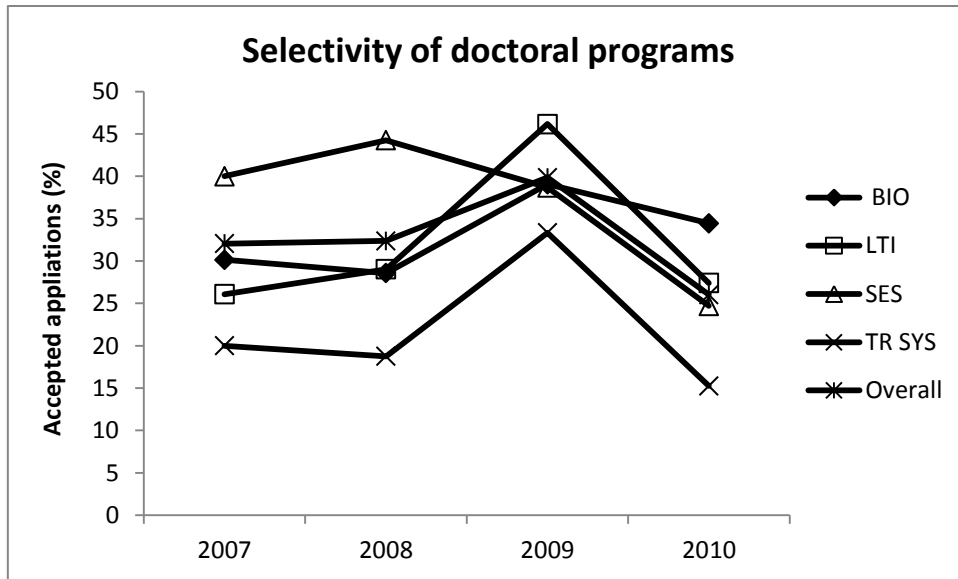


Fig. 11: Proportion of candidates admitted to each doctoral program over the past 4 years.

5.2. Master's programs

5.2.1. Applications

In its four editions the Master's programs have attracted a total of 353 applicants, with a progressively higher number of applicants each year (Fig. 12). The proportion of international applications for the CTIS Master's was significantly higher than for all the other Master's programs in the first three editions (Average 2007-2009: CTIS - 65%; SES - 12%; TME - 24%). In 2010 it was still the highest (87%) but the TME program also attracted a high number of international applicants (80%) (Fig. 13). Applicants were from all continents, from 36 different countries other than Portugal (Fig. 14).

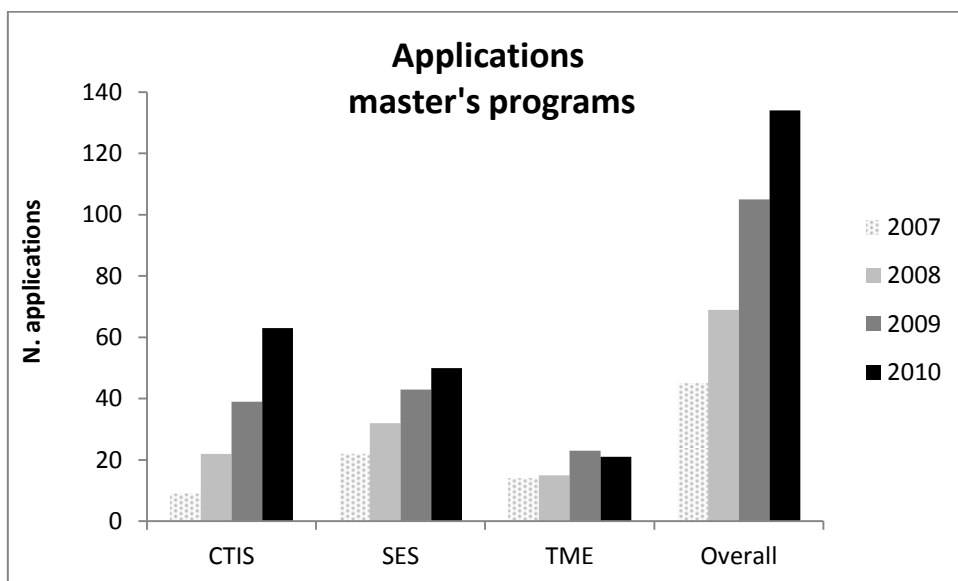


Fig. 12: Number of applications to Master's programs over the past years.

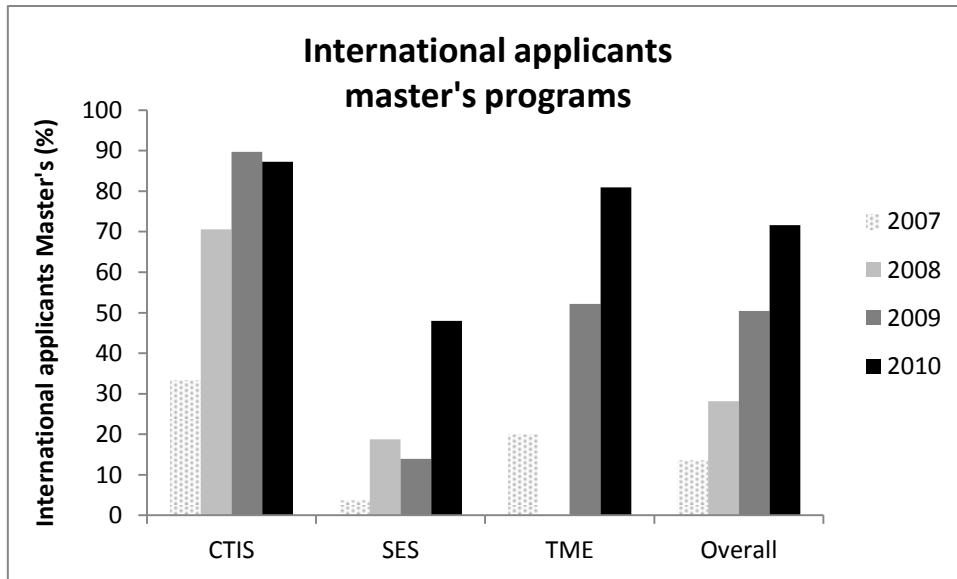


Fig. 13: Proportion of international applications to Master's programs over the past 4 years.

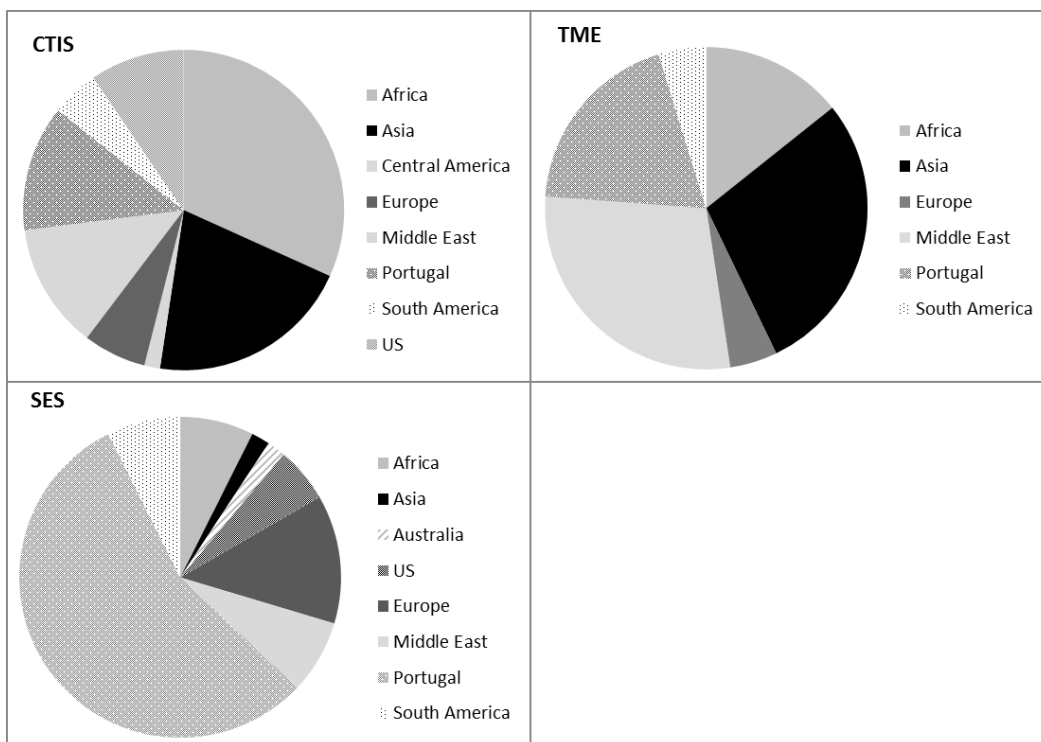


Fig. 14: Geographical origin of the Master's applicants (2010).

5.2.2. Students

There are currently 60 Master's students. In the last three years the Sustainable Energy Systems program has been admitting a significantly higher number of students than its peer programs in this network (Fig. 15).

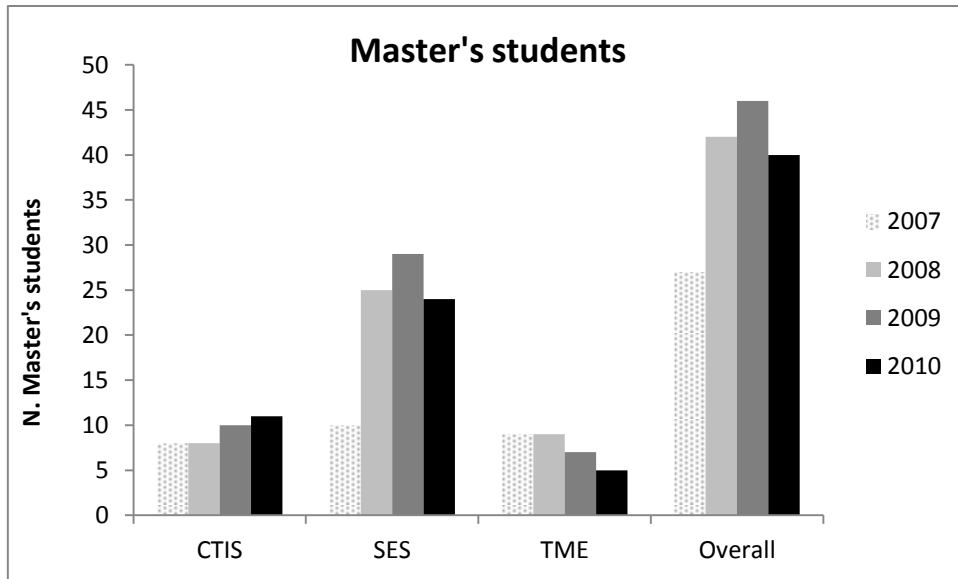


Fig. 15: Number of students admitted to the Master's programs over the past 4 years.

The overall proportion of international students is 61% (Fig. 16). Since its first edition the CTIS Master's has got 50% or more of international students. At present 76% of the CTIS Master's students (admitted in 2009 and 2010) are international. The equivalent figure for the SES and TME Master's is 16% and 17%, respectively. The students come from all continents, from 17 different countries (Fig. 17).

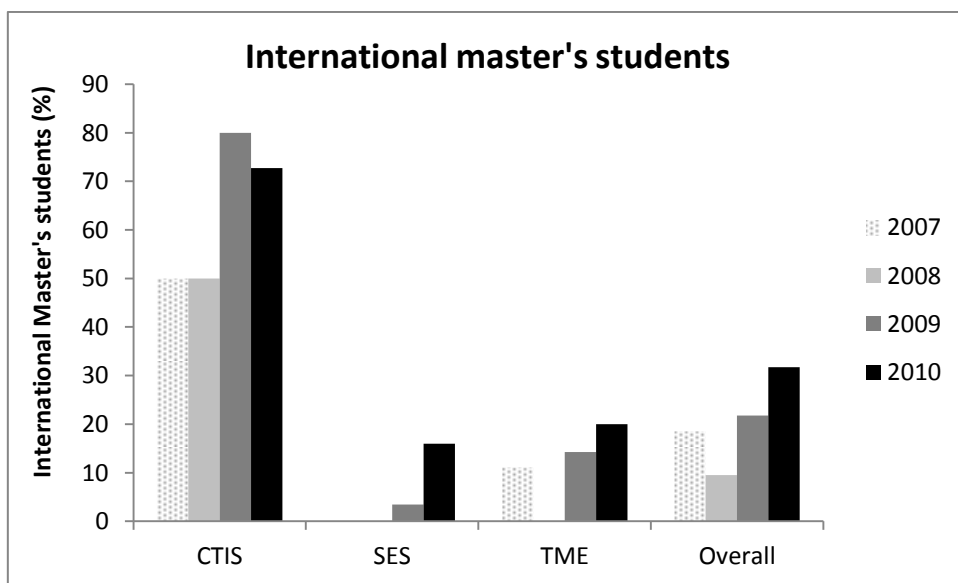


Fig. 16: Proportion of international students admitted in each Master's program over the past 4 years.

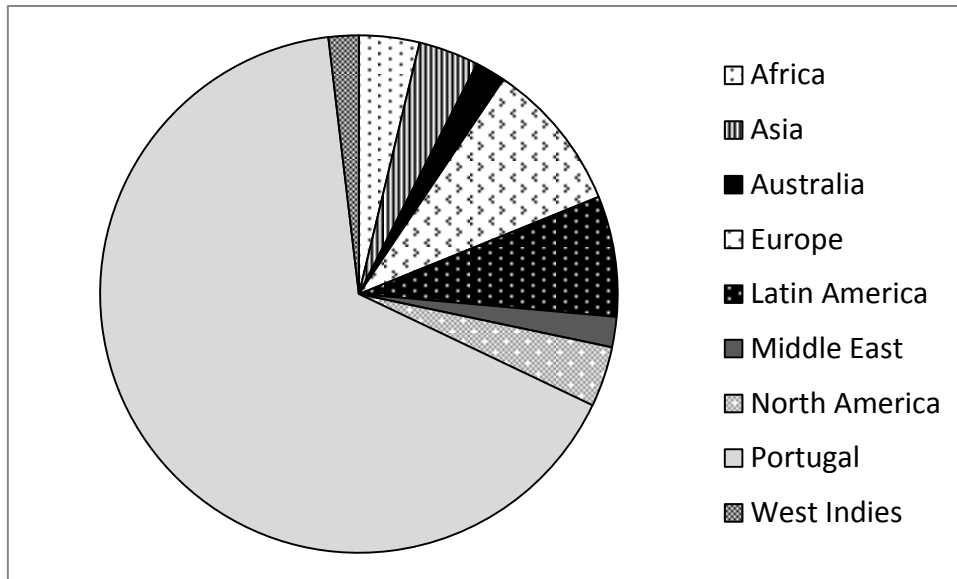


Fig. 17: Geographical origin of the Master's current students.

The 2010 admitted students come from Portuguese companies such as Martifer, SECIL, Robbialac, REN, Portugal Telecom, OGMA, Solvay Portugal, Alstom Portugal, Siemens Portugal, Ericsson, and EDP, and are graduates of prestigious universities including Yale, the University of Manchester and Chalmers University of Technology.

5.2.3. Selectivity

Around 50% of the candidates get admitted to the Master's programs. The overall degree of selectivity has progressively increased since the first year's edition (Fig. 18).

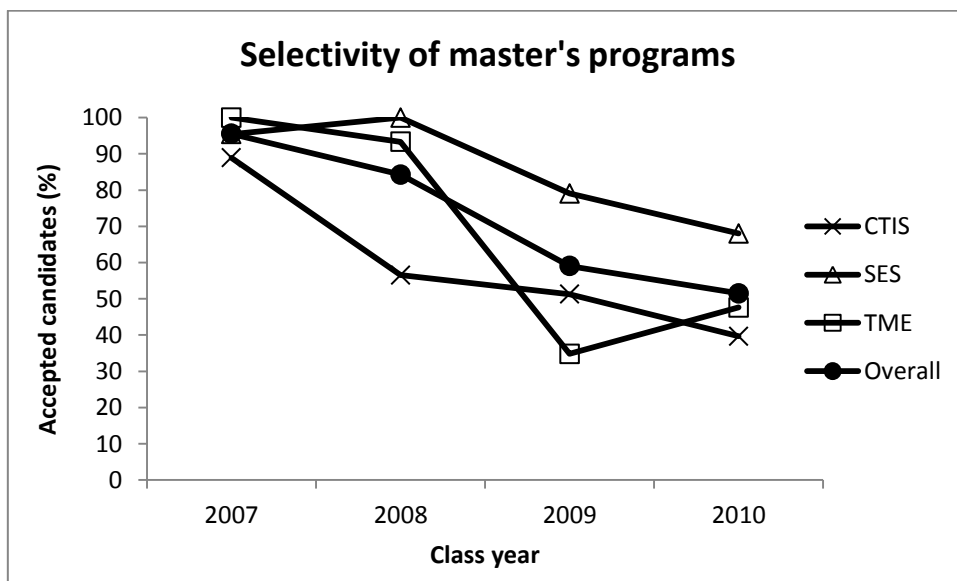


Fig. 18: Proportion of candidates admitted to the master's programs over the past four years.

5.3.MIT Research assistants (RAs)

There have been 300 research assistants (RAs) working on the MIT Portugal research projects at MIT over the past 5 years, an average of 60 RAs per year (Fig. 19).

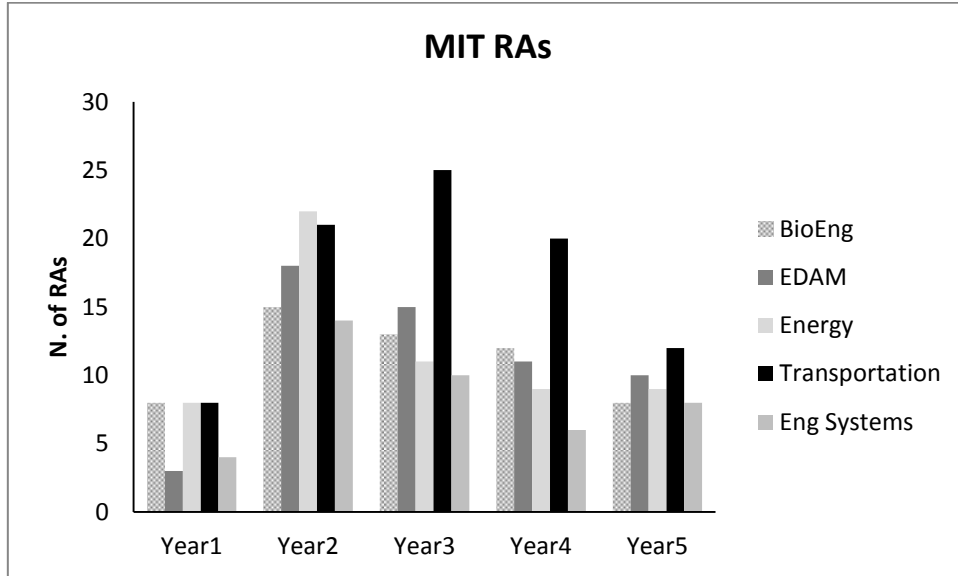


Fig. 19: Number of research assistants (RAs) at MIT over the past 5 years for each of the research areas.

6. Assessment of educational programs

6.1. Evaluating achievements

6.1.1. Overview

This section presents the findings of continuing program assessment which have been accompanying the MIT Portugal educational network since 2008. The section draws largely from research carried out in the context of a thesis project in MIT Technology & Policy Program (Pfothenauer 2010). The main sources are: comparative student survey that covers educational practices, student research, networking, industry linkages, and program administration; (faculty surveys both inside and outside MIT Portugal; a series of interviews with visiting students at MIT; and a variety of statistics obtained from the coordination office.

6.1.2. Re-designing engineering curricula and building human resources in innovation and entrepreneurship

MIT Portugal network's education under the trans-disciplinary Engineering Systems banner is strongly geared towards innovation, entrepreneurship, and industry linkages.

The network has succeeded in attracting a very specific student cohort to its graduate programs. Students have a background in industry work (both R&D & other) as well as other private sector work, amounting to 78% for MIT Portugal as opposed to 53% for other students.

Doctoral students are more prone to work in industry than their peers, and also to work as entrepreneurs. The students indicate a particularly high interest in working for their MIT Portugal industry research partner, which reflects the strategy of the network to involve industry affiliates in student research and education.

The MIT Portugal educational network has strongly promoted the non-academic job market to its students, and has broadly raised entrepreneurial spirit. Faculty emphasize that the program has fostered a more application-oriented approach towards teaching engineering materials, and that the program has benefited greatly from the highly diverse student body.

"MIT Portugal definitely contributes to acquiring these skills. [...] To my best knowledge, there is no existing PhD program in Portugal that has innovation in the curriculum, because they are focused on pure science. [...] All the students give terrific feedback. It is really interesting to them to explore that different area."

Students consistently rank their program higher with respect to key aspects in industry linkages. For example, the network focuses on entrepreneurship with a stronger concentration in economics and business principles. Students also appreciate the usefulness of their research to industry.

Faculty respondents confirm that their own teaching style has become significantly more geared towards innovation and management as a result of participating in MIT Portugal:

"I am also in a learning process in the MIT Portugal network, in this new engineering approach of bringing together economic aspects, management, etc."

Over the course of the network's existence, 23 new professorships were created for junior faculty to support the program's teaching and research goals. The research indicates that these faculty recruits are benefiting greatly from the program, receiving a noticeable "boost" in career opportunities, a rapid expansion of their professional networks, and important new input into their research work.

6.1.3. Attracting a strong, international cohort

MIT Portugal is successful in attracting an excellent student cohort. Students of the network are reported to show a greater degree of independence with their work, more precise achievement goals, and often a stronger commitment to achieve these goals. Students also enter their graduate studies with much higher expectations towards their program and put greater emphasis on the quality of education, the link between research and industry, internationalization of the program, the English language, and the employment prospects.

MIT Portugal has implemented a proactive international student recruitment policy paired with a competitive admission process. This high degree of internationalization is of great importance.

The international character of the program is supported by various mobility schemes. Students describe their MIT visit as extremely positive and highly influential, with strong gains in new methodological approaches or areas of interest. Visiting students report that their work has improved as a result of being at MIT. Several students have submitted articles or papers with MIT faculty/students as co-authors.

Portuguese junior faculty state that visits to MIT have been highly influential for their teaching practice. It has become a central part of the mobility scheme that these junior faculty audit MIT classes in order to gain a comparative perspective on how their subjects are taught and contextualized at MIT, or to acquire the competences to teach MIT courses at home.

The MIT Portugal student cohort differs with several other respects. Students display a different age structure than their peers. PhD students in MIT Portugal are on average 1.1 years younger than their counterparts. In contrast, MIT Portugal Master's students are on average 3.3 years older than students in comparable programs.

MIT Portugal students also differ with respect to their individual work experience. While for PhD students the levels of work experience are roughly comparable to others, 70% of MIT Portugal Master's students have 5 or more years of prior work experience, as opposed to 33% for their peers.

Furthermore, the network student cohort shows a significantly more balanced gender structure in its PhD programs. In comparison to a female fraction of 25.81% in other engineering programs, MIT Portugal raised the fraction to 45.95%.

6.1.4. Mobility and networking

An important aspect of the networking strategy is to introduce mobility. Students in the BioE PhD program, for example, study at various universities in Lisbon, Minho and Coimbra, and conclude with lab rotations all over country. The focus on mobility is facilitated by a modular term structure based on fast-rotating cycles of 2-week intensive courses. Furthermore, degrees are, for the first time in Portugal, jointly awarded in association by participating Portuguese universities. This mobility provides students access to the best teachers in the country and helps them to develop ties within the national research environment. Students have remarked on their mobility periods as highly enriching in experience and perspective, also contributing to a strong “cohort factor” and positive peer effects. This cross-curricular arrangement has no precedence in Portugal.

The high degree of student networking is correlated with a rise in student communication and connectivity. The assessment shows further that a larger fraction of MIT Portugal students is connected to other Portuguese research groups, both in terms of awareness and actual contact. The percentage of other students not knowing or being in contact with any other groups is 51% and 63%, respectively, as opposed to 40% and 36% for MIT Portugal students. In particular for actual contacts the MIT Portugal cohort supersedes its peers by a factor of 1.75.¹¹

Networking is also constitutive on the faculty level. Faculty respondents perceive the increased networking and cooperation as one of the most tangible and desirable program outcomes:

“Without MIT and outside the network, [interaction and networking] is very small. This is a practice that MIT Portugal started – it is an achievement of the network. Before, the level of relation between the Portuguese universities was very scarce.”

“Portugal never had a program for cooperation inside Portugal: I mean a real program. It’s senseless to cooperate inside the country at this moment, where there is no funding and bureaucracy is too much.”

MIT Portugal faculty, who continue to teach at other classes in their home institutions, have remarked on how MIT Portugal has positively affected their overall teaching quality. They also report that they have been actively approached by their colleagues about the contents they teach and methods they use.

The educational network has served as a blueprint for the design of new programs at Portuguese universities (e.g. at Universidade Nova de Lisboa). This active copying is partly due to the involvement of MIT Portugal faculty in the course formation process.

Research and networking has helped launching a number of initiatives that widen the network, including “Stemcellnet,” the “Sustainable Cities Forum,” or “ISCTE-MIT Portugal IEL.”

Finally, MIT Portugal has stimulated one instance of an excellence cluster in Portugal – in sustainable energy systems (SES) at the University of Coimbra. One faculty recalls:

¹¹ The number for contacts refers only to students who have indicated that they know at least one group. In other words, if a student knows other groups, how likely is he/she to actually be in contact with them?

“We did not realize that there was a group of people here in the university, a critical mass, to develop educational programs and research in the energy area. [But] we are about 26 faculty members and 4 R&D institutes who have joined efforts, and MIT was the motivation for this – the wish to be part of the program. [...] To monitor our activities in the energy area in Coimbra, we have set up a council of [...] about 20 company representatives who meet with us and the students once or twice a year. We tell them what we are doing, and they tell us what they think about what we are doing, and what they would like us to do more. This is nothing that was suggested or imposed by MIT. But it’s something that indirectly, like many things, relate to this MIT Portugal Program.”

The network has also facilitated the formation of novel administrative capacities. The complexity of the program has led to a demand to enhance professional support structures for education and research at Portuguese universities, ranging from visa issues and scholarship timing for international students, to inter-lab mobility and money-follows-researcher situations, to video-lecturing, teacher training and support, and the facilitation of industry-linkages.

6.1.5. I-teams

The i-teams, a major entrepreneurship educational piece at MIT was adapted to work in the Portuguese universities as a two-stage approach:

- *Innovation Leadership course* : A two-week action-based introductory course on innovation early on in the program empowers students with a can-do attitude and basic skill-set to engage in a hypothesis-driven exploration of technology impact. The course was designed as a “crash course” to MIT’s approach and attitude about innovation. Content on basic business skills, interaction in academia, market exploration, innovation management, or IP, was used as adequate given student backgrounds. The course succeeded in opening student eyes to the process of innovation: bridge from research to society, connect real problems and communicate innovations to a broader audience.
- *Bio-teams*: a semester long course in which teams of students explore the go-to-market feasibility of current Portuguese technologies. The course implements i-Teams concepts in a unique set-up: students are in different Portuguese locations based on their ongoing research projects, they meet three times in the same location that coincide with events, and have mentoring, milestones, and lectures throughout the semester.

Bioengineering and EDAM implemented variants of the innovation leadership course. Additionally, content was designed for a pre-module to introduce students to the full innovation program and the value of IP and, in connection with IP, the danger and inadequacy of plagiarism. Over 400 students, faculty, guest lecturers, and audience guests, have participated in BioTeams and EDAM’s innovation classes to date.

Bio-teams host the community in three events: to select technologies for the course, get feedback in the mid-terms and showcase the final results.

Innovation in bioengineering has had immediate impact on how students approach and understand technological innovation. As an example, Cell2B is a recently incorporated and funded biotech startup based on Portuguese technology, developed by students from the first

cohort of the program in parallel with their PhD studies, and participated in the inaugural Venture Competition.

- **Visitors at MIT:** Pedagogy behind the technology innovation courses was shared with over 20 Portuguese faculty hosted in i-Teams at MIT. Many joined the bio-teams team, some developed new courses borrowing from the pedagogy of i-teams.
- **Research:** Numerous research projects including one PhD project in innovation in bioengineering addressed the topic of innovation under the research framework.
- **Innovation events :** 6 yearly innovation events were organized, 3 for BioTeams and 3 for IEI.

The following table provides an overview of the main activities and findings taken during the i-teams activity in Portugal.

Innovation team activities and findings from MIT Portugal

Innovation Activities		Description	Key Learning
<i>Bio-engineering</i>	Innovation module	<p>Designed of a “innovation leadership” action-based 2-week course. Students are expected to appreciate how to use existing and new skills, network, and intellectual property; to build innovations out of technology research and engage effectively with the ecosystem to test their hypotheses of impact.</p> <p>The learning goal is to empower students to approach innovation with a can-do attitude with a quick overview of business basics, interaction with academia, and interaction with the market as pertinent for the development of technology innovations, and referred to Portuguese reality.</p>	<ul style="list-style-type: none"> • Critical to awaken in the students the entrepreneurial and can-do spirit that is a given at MIT. Helps students replace critique by action. • Help strengthen bonds in a cohort of students and connect with previous cohorts • Can be used as an introduction to technology innovation in all areas with students of different backgrounds.
	<i>Bio-teams</i>	<p>Adapted from i-Teams at MIT: student teams use a semester to explore go-to-market strategies for current Portuguese technologies, and work with the PI, a volunteer from the community, and coaching from faculty. Faculty and industry professionals identify candidate technologies. Students form teams around these technologies based on common interest. Lectures alternate with team time throughout an entire semester. Deliverables are designed as milestones to advance in the project.</p>	<ul style="list-style-type: none"> • Mechanisms to coordinate students that are not co-located, with “distributed” lectures and faculty. • Due to already distributed nature, course can be scaled up to a larger number of students, for instance from different concentration areas. • Exposure to brief innovation leadership course is critical for students to engage effectively in distributed course
<i>EDAM</i>	Innovation Management 2-week course	<p>This is a variant of the innovation module of bioengineering. In the first week, students receive theoretical content on innovation management. In the second week (normally a few months later) students engage in teams in an action-driven exercise to find a path to commercialization for a Portuguese technology. Students are given an extra month to finish the project before turning in a brief report. EDAM has a semi-professional curriculum with professional master and PhD students.</p>	<ul style="list-style-type: none"> • The mix of professional and full-time students is positive for the program, with the emphasis on time management to have the most efficient contribution from the professionals. • Rescheduling the module could probably increase the students’ attention as well as the project quality.
	Connection with UTEN and TTOs	<p>Technologies used in the innovation module of EDAM were sourced from the different TTOs in coordination through UTEN. Representatives from TTOs presented the technologies to students to guide team formation. Resources from these offices were made available to students to analyze the IP and as a repository of the ongoing efforts to license or commercialize the technologies.</p>	<ul style="list-style-type: none"> • The connection with UTEN is desirable but requires additional effort to seek the engagement of PIs as a resource for the students. • UTEN is mainly focused on commercialization (license/startup) rather than assessing “what to do with the technologies” through hypothesis driven exploration of the market.

6.2. Student's evaluation of educational programs

Student evaluation is carried out in each program and for each course individually, through online anonymous questionnaires. Students are invited by email to answer to the questionnaire, on a volunteer basis. The main topics evaluated are the overall quality of the program and for each course, the quality of teaching of each course (by lecturer), the contribution of the course for the student's generic and specific skills and assessment of student's learning. In the Sustainable Energy Systems and Engineering Design Manufacturing (EDAM) areas both the PhD and the Master's programs are evaluated as one as the students from each degree attend the classes as one group. The Transportation PhD program is implementing a student's evaluation program this academic year. A summary of the evaluation of the educational programs by the students over the years is presented in figures 20 and 21. On a scale of 1 to 7, students scored 5.2 for the overall program and 5.4 for the teaching quality. The Bioengineering program is the one receiving the highest scores.

Students highly praise the high level of interaction with faculty on which this course is based.

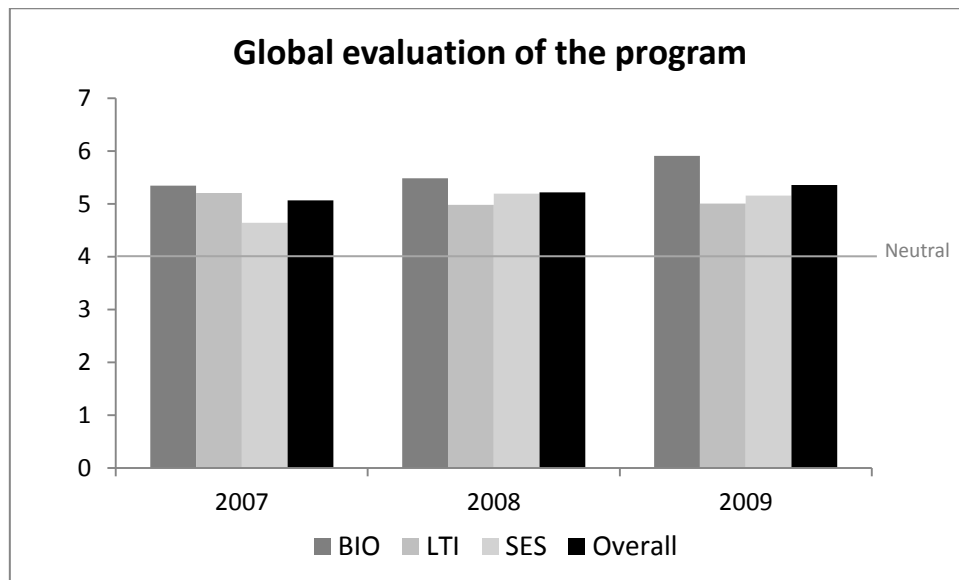


Fig. 20: Global evaluation by students of all the evaluated educational programs (1 - poor, 4 - neutral, 7 - excellent).

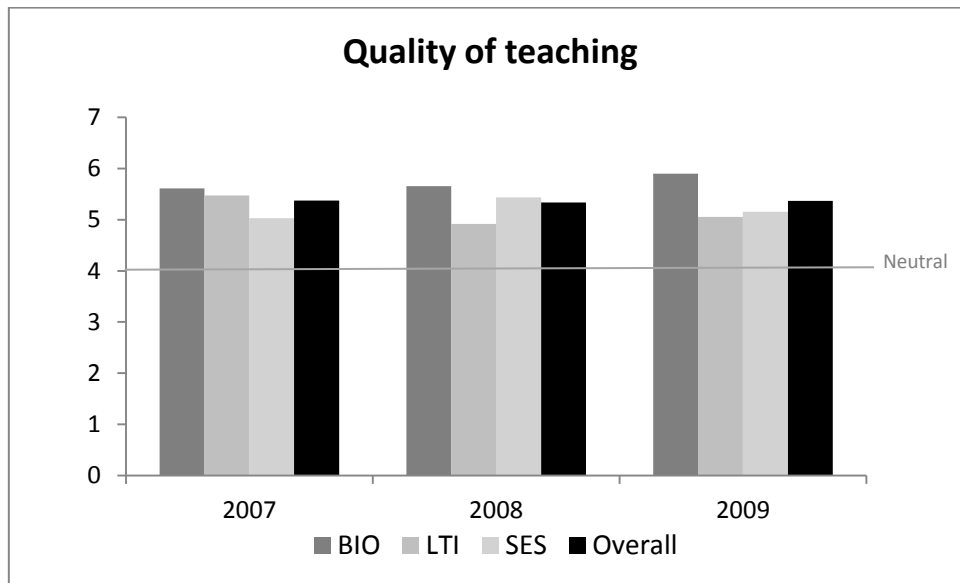


Fig. 21: Teaching evaluation by students for all the doctoral programs that were evaluated by students (1 - poor, 4 - neutral, 7 - excellent).

6.3. Student's evaluation of the network

6.3.1. Overview

This section reviews the evidence from the suite of 2010/2011 evaluation surveys to students and alumni of the MIT Portugal network. This suite of surveys contained the following questionnaires:

- **Alumni:** Sustainable Energy Systems Master's (6 respondents); Complex Transportation Infrastructure Systems Master's CTIS (5 respondents) (a total of 11 out of 56 invited alumni);
- **Doctoral students (2nd, 3rd and 4th years):** Biongeering BIO (44); Leaders for Technical Industries LTI (35); Sustainable Energy Systems SES (62); Transportation Systems TR SYS (22) (a total of 163 respondents out of 203 invited students);
- **Entering students** (students who were admitted in the Program in 2010): Biongeering BIO (17); Leaders for Technical Industries LTI (11); Sustainable Energy Systems PhD SES (21); Transportation Systems TR SYS PhD (8); Complex Transportation Infrastructure Systems CTIS Master's (10); Sustainable Energy Systems Master's (8); (a total of 75 respondents out of 112 invited students);
- **Exiting graduate students** (students who will finish their degree very soon or have finished it recently): Sustainable Energy Systems Master's (14); Technology Management Enterprise Master's (8); Complex Transportation Infrastructure Systems CTIS Master's (13) (a total of 35 out of 59 invited students).

Altogether, some over 66% of eligible students completed a very comprehensive evaluation questionnaire.

6.3.2. Alumni survey

The responses of the alumni about the MIT Portugal network are based on a low number of respondents (11):

- Over 70% rated the level of their supervision, the intellectual and overall quality of the network, and the quality of the research, as either very good or excellent;
- Over 70% regarded their working relations with faculty and fellow students as either very good or excellent;
- Over 60% believed they felt competent to develop a career in business and to undertake innovative initiatives in complex technology projects and management;
- Between 50% and 60% felt that they were now in a position to evaluate technological innovation, to create a business plan, to recruit the right people for industry, and to evaluate the economic case for new technology, as well as to present research findings in a major international conference;
- 5 of 7 respondents who are now employed stated that they had entered a job directly related to their academic experience in the MIT Portugal network;
- 10 of the 11 respondents were rather or very satisfied with their career as a result of participating in the MIT Portugal network;
- 73% would recommend the university they attended to others, and 45% would recommend their educational program to a student in another field of study.

6.3.3. Doctoral student survey

The doctoral students were very supportive of the MIT Portugal network as a whole:

- Over 80% strongly agreed or agreed that the quality of their supervision, access to their supervisors, and their faith in the support of their supervisor in advancing their career was of the best;
- The overall satisfaction with all aspects of supervision was over 67%;
- Over two thirds met their supervisor either every week or every fortnight;
- Between 50 and 60% rated the intellectual quality of the faculty of the and their fellow graduates as either excellent or very good;

Comparison of supervision between collaborating Portugal universities and MIT

- Around 30% of the doctoral students who responded to the survey experienced supervision from MIT. 54% and 28% strongly agreed and agreed, respectively, that their supervisor in Portugal performed their role very well overall. 47% and 27% strongly agreed and agreed, respectively, that their MIT supervisor performed their role very well overall;
- 48% in this survey with supervision in Portugal strongly agreed that their supervisor promoted their professional development, while the corresponding figure for MIT supervisors is 41%;

- 38% of supervisors in Portugal were rated very helpful in supporting research and writing scientific papers, while the MIT supervisors were rated by 42% of students as being very helpful in these regards;
- 45% of students in Portugal saw their supervisor once per week, while 26% of those supervised at MIT saw their supervisor once per week. The figures for meetings with supervisors every two weeks are 16% and 14%, respectively.

6.3.4. Entering student survey

- Over 80% looked for the intellectual and research excellence of their faculties/potential supervisors as the main reason for joining their educational program;
- Over 80% also regarded that link with MIT, its international links generally, and its broad interest in interdisciplinarity as a key factors in selecting the program;
- Over half felt that the MIT Portugal network was understood and well regarded by faculty and students on their campuses.
- Between 70 and 90% expect their experience in their program to be extremely helpful in improving their creative, literary and research skills, along with interdisciplinarity, and ability to communicate with policy leaders and opinion formers;

6.3.5. Exiting student survey

- Between 70 and 80% felt that they were treated with respect by faculty, got on well with their fellow students, recognized that the Program supported their personal and professional goals;
- Over 70% believed that the network was respected by faculty, 60% noted that the network was well advertised on their campuses, but less than 20% felt they were well integrated on their campuses with other students;
- Over 80% claimed that their experience with the network helped them to understand more about how business and industry works, to improve their ability to work outside academia, to upgrade their understanding of economic and business principles, and to understand better the role of innovation and technology transfer;
- Of the SES graduates, 4 were in jobs directly related to their educational experience in the Program while 8 were in jobs not directly related, in CTIS the numbers were 4 in direct job links with 2 negotiating over jobs with direct links, and in TME 3 were in direct job links, and 4 in jobs not directly connected to their educational research. Between 75 and 85% said that their experience with the MIT Portugal network was instrumental in giving them the capability for employment because of the intellectual and training rigour they experienced.

7. Perspectives for the future

7.1. Lessons learned

The MIT Portugal Program is a program with multiple objectives for both MIT and the Portuguese Universities and Companies. In Portugal primary concerns included human resource development, educational reform, focusing on high priority research areas in knowledge based industries, fostering university/industry relations, creating an eco-system to foster innovation and entrepreneurship. The Portuguese program is the largest international program MIT had undertaken in Europe and the first program involving partnerships with many universities in the host country. All other MIT international programs involved only one or two universities in the partner country.

MIT Portugal program is designed to be a long-term partnership. This recognized that it would take at least a decade for the full impact of these programs on economic and societal development to be realized. It is beneficial to now examine what are the primary lessons learned from, and how might those lessons improve future international collaborations.

- **Effective world class PhD programs can be created at the national level** - For the first time, national PhD programs were created in Portugal in each of the four focus areas. Rectors and faculty from three or more universities agree to cooperate in the development and delivery of these novel doctoral programs. The joint university doctoral programs can realize foundational curriculum across the entire program in the next five years. Suggested curriculum modules include Innovation of Technological Systems, Systems Thinking and Methodology, and Leadership Development, which can be offered to all MIT Portugal Program doctoral students.
- **Institutionalize and Disseminate the Educational Programs and Innovations throughout the Portuguese University System.** It is very difficult to implement fundamental change in any educational system and Portugal is no exception. An essential component of the next five years should be the creation of a new Graduate Studies Institute that will be the institutional home of the Program. It will be virtual in that it will not have any physical infrastructure, and it will work with all the participating universities to assist in developing and institutionalizing best practices among educational programs as well as to facilitate faculty mentoring and review committees, and provide support and communications for the major Research Programs.
- **Portuguese Faculty Benefit From Spending One or More Semesters at MIT** - All Portuguese faculty who had the opportunity to spend time at MIT emphasized the value of the experience. They were able to observe first hand the MIT culture in education, research and technology transfer. All Portuguese faculty involved in the teaching program should be required to spend at least one semester at MIT as a faculty fellow. This will facilitate the transfer of teaching responsibilities, and leverages the teach-the-teacher model, which has been found to be very successful. Funding

must be provided in the Portuguese budget to support these visits and to provide for substitute teaching in Portugal while the faculty member is at MIT.

- **The student research experience at MIT was very successful** – Over 75 Portuguese students had the opportunity to spend time at MIT working on their research. Visits lasted from several months to two years. There were some initial difficulties in implementing the program, but based on student feedback necessary improvements were made to insure that students had proper supervision and interaction with MIT students and faculty. The program is now operating very effectively and should be continued in the future.
- **International Students Will Select International PhD Programs** - An objective of the PhD programs is to attract the best and the brightest not only from Portugal but from all over the world. That objective was largely achieved since the number and quality of international students has increased each year. Students are applying from the best universities in the world, but increased quality and excellence in student applicants is an ongoing effort to be recognized as a leading European Program. MIT Portugal Program students had the opportunity to spend significant time at MIT working on their doctoral research. Visits lasted from several months to two years. The visiting MIT Portugal student experience is a critical and unique aspect to assure the highest level of research accomplishments and should be continued and adequately funded.
- **Executive Masters Programs Help Create Effective Linkages to Industry** - These programs are effective in several ways. Company employees enroll in the programs and then return to their companies. Students without company sponsorship experience an internship at a company and then are hired by the company (e.g., Rolls Royce). An important improvement occurred during the first phase of the MIT Portugal Program when each executive program was required to appoint an industry co-director. This provides an important mechanism for industry to play an active role in curriculum development and other important decisions relating to the program.
- **Support For Portuguese Post Docs Is Essential** – The goal is to attract world-class researchers to Portugal. In the first five years we lost some of our most promising young Portuguese researchers because there were no long-term faculty career opportunities. These promising researchers should have the opportunity to obtain permanent faculty appointments in Portuguese universities.
- **Cross Cutting Educational Courses Are Very Effective** - Cross cutting courses in Leadership and Innovation were taught in several educational programs and were very well received. Other cross-cutting foundational courses could be introduced to enhance Program cohesiveness and establish quality control in the curriculum.

APPENDICES

Table I: Total amount of students from Portugal participating in MIT Portugal visiting MIT since the beginning of the Program until the end of January 2011. Source of information for the PhD programs: students; Executive Master's: local program's coordination.

		BIO	EDAM	SES	TR SYS	Total
PhD programs	N. of students who have been to MIT	22	13	18	7	58
	N. of months they spent there	262,5	47.75	96.65	68	474.9
	N. of other students who will visit MIT in the near future	9	11	14	11	45
	N. of months students intend to spend at MIT in the near future	186	40	83	121	430
Executive Master's programs	N. of students visiting MIT (two weeks stay)			45		45
	N. of students who will visit MIT in the near future (two weeks stay)			19		19

Table II: Amount of students from Portugal participating in MIT Portugal visiting MIT as foreseen in the MIT Portugal Program contract (adapted from Table VII.2 of the agreement)

	BIO	EDAM	SES	TR SYS	Eng Syst	Total
Year 1	6	4	3	3	1	17
Annual average from year 2 to year 5	8-10	6	8	6	3	31-33
Total for the 5 years	38-46	28	35	27	13	141-149

Table III: Teaching Faculty of the Bioengineering Systems area.

Name	Institution
Ana Ricardo	FCTUNL
Ali Khademhosseini	MIT
Anthony Sinskey	MIT
António Vicente	UMinho
Arlindo Oliveira	IST
Arsénio Fialho	IST
Bruce Tidor	MIT
Carlos Duarte	CNCUC
Cecilia Roque	FCTUNL
Charles Cooney	MIT
Clara Reis	IGC/ITQBUNL
Claudia Silva	IST
Claudio Soares	ITQBUNL
Daniel IC Wang	MIT
Dava Newman	MIT
Elly Nedivi	MIT
Estela Bicho	UMinho
Eugenio Ferreira	UMinho
Fernanda Llussá	FCTUNL
GK Raju	MIT
Guilherme Ferreira	IBB
Hugh Herr	MIT
Isabel Rocha	UMinho
Joao Conde	IST
João Crespo	FCTUNL
Joao Malva	CNCUC
Joao Mano	UMinho
Joao Nuno Moreira	CNCUC
Joaquim Cabral	IST
Jorge Martins	IST
José Menezes	IST
José Teixeira	UMinho
K.Dane Wittrup	MIT
Larry Young	MIT
Ligia Rodrigues	UMinho

Name	Institution
Lino Ferreira	CNCUC
Luis Almeida	CNCUC
Luis Fonseca	IST
Luis Lages	UNL
Luis Rocha	UMinho
Luísa Vasconcelos	ITQBUNL
Manuel Mota	UMinho
Manuela Fonseca	IST
Manuela Gomes	UMinho
Maria Reis	FCTUNL
Mario Grãos	CNCUC
Marta Moita	IGC/ITQBUNL
Miguel Castelo Branco	CNCUC
Miguel Prazeres	IST
Miguel Prazeres	IST
Miguel Rocha	UMinho
Miguel Silva	IST
Miguel Teixeira	IST
Nuno Neves	UMinho
Nuno Sousa	UMinho
P.Flores	UMinho
Paula Agostinho	CNCUC
Paula Alves	ITQBUNL
Paula Hammond	MIT
Pedro Saraiva	UC
Robert Langer	MIT
Rodrigo Cunha	CNCUC
Rui Oliveira	FCTUNL
Rui Reis	UMinho
Sergio Santos	CNCUC
Stan Finkelstein	MIT
Thomas Allen	MIT
Zach Mainen	IGC/ITQBUNL

Table IV: Teaching Faculty of the Engineering Design and Advanced Manufacturing (EDAM) area.

Name	Institution
A. Paisana	UMinho
Alcibiades Guedes	FEUP
Américo Azevedo	FEUP
Ana Pova	IST
Anne McCants	MIT
António Araujo	FEUP
António Ribeiro	IST
Arlindo Silva	IST
Bernardo A. Lobo	FEUP
Carlos Freitas	IST
Dan Whitney	MIT
Eduardo Beira	UMinho
Elsa Henriques	IST
F. Jorge Alves	FEUP
Francisco Pires	FEUP
Frank Field	MIT
Gustavo Dias	UMinho
J. Mendonça	FEUP
Jean-Pol Piquard	FEUP

Name	Institution
Jermery Gregory	MIT
Joel Clark	MIT
Jorge Pinho de Sousa	FEUP
Júlio Viana	UMinho
L. Perez Brava	MIT
Lia Patrício	FEUP
Luis Faria	IST
Luis Rocha	UMinho
M Sameiro Carvalho	UMinho
Madalena Araújo	UMinho
Mihail Fontul	IST
Partha Gosh	MIT
Paulo Peças	IST
Qi Hommes	MIT
Randy Kirchain	MIT
Ricardo Simões	UMinho
Rui. M. Baptista	IST
Stanley Gershwin	MIT
Valério Carvalho	UMinho

Table V: Teaching Faculty of the Sustainable Energy Systems area.

Name	Institution
Adélio Gaspar	UC
Almerindo Domingues Ferreira	UC
Alvaro Gomes	UC
Ana Maria Camanho	FEUP
Aníbal Traça de Almeida	UC
António Martins	FEUP
Carlos Henggeler Antunes	UC
Carlos Pereira da Silva	ISEG
Carlos Silva	IST
Claúdio Monteiro	FEUP
Divo Quintela	UC
Eduardo Barata	UC
Eduardo de Oliveira Fernandes	FEUP
Fausto Freire	UC
Filomena Garcia	ISEG
Harvey Michaels	MIT
Humberto Jorge	UC
Ignacio Perez Riaga	MIT
Isabel Mendes	ISEG
Isabel Proença	ISEG
Isabel Proença	FEUP
Isabel Torres	UC
João Coutinho Rodrigues	UC
João Peças Lopes	FEUP
João Tomé Saraiva	FEUP
John Fernandez	MIT

Name	Institution
José Bandeirinha	UC
José Baranda Ribeiro	UC
José Costa	UC
José Luis Alexandre	FEUP
Luís Adriano Oliveira	UC
Luis Cruz	UC
Luis Dias	UC
Manuel Carlos Gameiro da Silva	UC
Manuel Matos	FEUP
Marco Reis	UC
Maria Helena Vasconcelos	FEUP
Miguel Águas	IST
Muradali Ibrahim	ISEG
Nicola Deblasio	MIT
Nuno Simões	UC
Pacheco Coelho	ISEG
Patrícia Silva	UC
Paulo Ferrão	IST
Pedro Saraiva	UC
Raimundo Mendes da Silva	UC
Rita Sousa	FEUP
Steve Connors	MIT
Tiago Domingos	IST
Tiago Farias	IST
Vitor Leal	FEUP
Vladimiro Miranda	FEUP

Table VI: Faculty of the Transportation Systems area.

Name	Institution
António Couto	FEUP
Adelino Ferreira	FCTUC
Alexander Chlan	IST
Alexandre Gonçalves	IST
Álvaro Costa	FEUP
Álvaro Seco	FCTUC
Américo Pires da Costa	FEUP
Ana Bastos Silva	FCTUC
Anabela Ribeiro	FCTUC
António Pais Antunes	FCTUC
Bruno Santos	FCTUC
Carlos Henggeler Antunes	FCTUC
Carlos Rodrigues	FEUP
Edgar Blanco	MIT
Filipe Moura	IST
Gonçalo Correia	FCTUC
João Abreu	IST
João Claro	FEUP
João Coutinho	FCTUC
João Duque (ISEG)	ISEG
John Akula	MIT
Jorge Freire Sousa	FEUP
Jorge Pinho de Sousa	FEUP
José Antunes Ferreira	IST
José Neves	IST
José Viegas	IST
Joseph Sussman	MIT
Judith Layzer	MIT
Luís de Picado Santos	IST
Manuel Gameiro	FCTUC
Maria Teresa Dias	FEUP
Moshe Ben-Akiva	MIT
Paulo Teixeira	IST
Pedro Bizarro	FCTUC
Richard de Neufville	MIT
Rosário Macário	IST
Rui Marques	IST
Rui Oliveira	IST
Teresa Gamito	FCTUC

Executive Program Management

Program Directors:

Paulo Ferrão

Daniel Roos

Scientific Coordination:

1. Stem Cell Engineering for Regenerative Medicine:

Dava Newman

Joaquim Sampaio Cabral

2. Sustainable Energy and Transportation Systems:

Chris Zegras (co-director)

John Fernandez (director)

José Viegas (co-director)

Paulo Ferrão (director)

3. Materials and Design Inspired Products:

Chris Magee

Olga Carneiro

4. Engineering Systems Fundamentals

Dan Roos

João Sousa

Doctoral Program Coordination:

1. Bio-engineering Systems:

Bruce Tidor

Manuel Nunes da Ponte

2. Sustainable Energy Systems:

David Marks

João Peças Lopes

3. Transportation Systems:

Antonio Pais Antunes

Richard De Neufville/Josh Jacobs

4. Leaders for Technical Industries :

Joel Clark

Manuel Freitas

Master Programs Coordination:

1. Sustainable Energy Systems:

António Vidigal - EDP

Carlos Santos Silva

David Marks

2. Complex Transport and Infrastructure Systems :

Josh Jacobs

Luis Picado Santos

Jorge Salles Gomes – Brisa

3. Technology Management Enterprise :

Joel Clark

António Torres Marques